What lurks in the heart of the Milky Way? p. 30

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OCTOBER 2015

SECRETS FROM TITAN'S SEAS

Learn about the mysterious lakes on Saturn's largest moon p. 24

The Cassini spacecraft peers through Titan's haze to reveal sunlight reflecting off the north polar seas.

New life for old refractors p. 44

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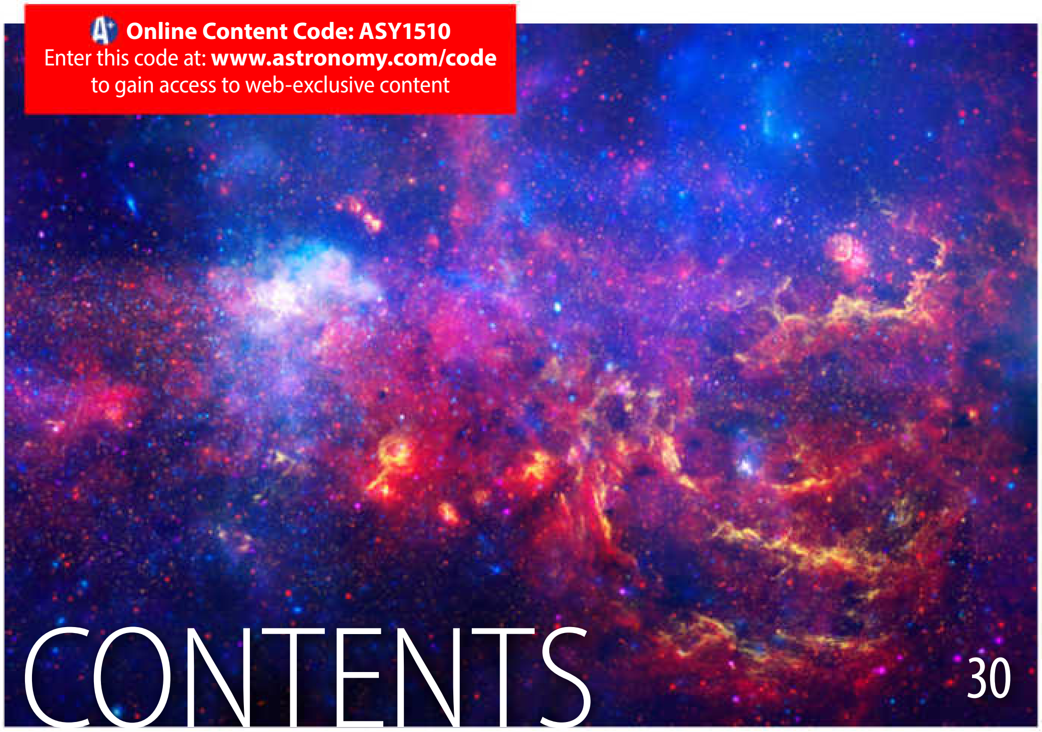

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NASA/JPL-CALTECH/UNIV. OF ARIZONA/UNIV. OF IDAHO

ON THE COVER

Saturn's largest moon, Titan, reveals sunlight reflecting off its north polar seas in this Cassini composite image.

FEATURES

COLUMNS

QUANTUM GRAVITY

IN EVERY ISSUE

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FROM THE **EDITOR**

BY DAVID J. EICHER

Listen in on the universe

Do you ever listen to the universe? If so, you'll know that it's talking to you. You can hear the sounds of the cosmos by wandering out on a dark night and immersing yourself in a panorama of stars, turning off radios and phones and simply listening to nature. It's a relaxing experience, one that virtually everyone who has done much stargazing is familiar with.

But there's also another way to listen to the universe. And that comes from listening to what's happening with some of the most impressive movers and shakers in astronomy. (OK, it's not listening to the universe, but only a select few of the beings that have popped up within it.)

Back in January, I began a series of hourlong audio podcast interviews with notable figures in astronomy, cosmology, and planetary science. I want you to know that this bonus material is out there on our website, ready to listen to at your convenience. You can find the interviews at www.Astronomy.com/superstars.

In this series, sponsored by Celestron, the world's leading manufacturer of telescopes, we have already explored a wide range of subjects.

Renowned astrophysicist Jeff Hester spoke about his iconic Hubble "Pillars of Creation" image, knowledge in the age of the Internet, recent changes in scientific thinking, and more. (Hester subsequently became a magazine columnist for us!)

Garik Israelian, founder and director of the Starmus Festival, told us about the most amazing science festival in the world, which next year will pay special tribute to Stephen Hawking, with an all-star cast of 10 Nobel Prize speakers, astronauts and cosmonauts, science-obsessed rock musicians, and other celebrities.

Head of the New Horizons mission Alan Stern spoke at length about the historic exploration of Pluto and its system of moons that took place this year.

Astronomer Debra Fischer of Yale University walked through an extensive exploration of exoplanet research — where we stand, where things are going, and the likely surprising research and discoveries that may be around the corner.

I also had a magnificent conversation with Rusty Schweickart about his Apollo 9 mission. Hearing firsthand from the participant about being in an Apollo liftoff, the subsequent orbital operations, and the overall experience was incredible. I hope you'll agree with me. We also talked about another of Schweickart's current passions, asteroid threats and planetary defense of Earth, including his involvement in Asteroid Day.

Those of you who know of Seth Shostak, the SETI Institute's senior astronomer, know what a hugely entertaining speaker he is. You can check out our conversation about life in the universe and other wonderful related topics.

And I have had great chats with Gerard van Belle of Lowell Observatory, Bruce Balick of the University of Washington, and others. Check out the entertaining "Superstars of Astronomy" podcasts, and let me know what you think. I'll be listening, too.

Yours truly,

David J. Eicher
Editor

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Astronomy

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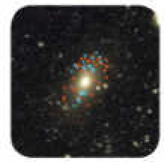
EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH . . .

HOT BYTES>>

TRENDING TO THE TOP

MARTIAN MILESTONE
NASA's Mars Odyssey spacecraft hit a landmark 60,000 Red Planet orbits in June. At 14 years, it's the longest-operating martian instrument ever.

MOON SWIRLS
Simulations show odd, bright lunar features called swirls can be caused by comets crashing into the Moon over the last 100 million years.



GOBBLING GALAXY
Giant elliptical galaxy Messier 87 consumed an entire galaxy in the last billion years, scientists saw by watching planetary nebulae movement.

SNAPSHOT

Why did Venus turn inside out?

Three-quarters of a billion years ago, our "sister planet" globally resurfaced.

Venus is unmistakable in our sky. Never straying terribly far from the Sun, it blazes brilliantly either in the evening or morning. But along with its brilliance, Venus hides a secret.

Many inner planets and moons preserve a great record of ancient impacts from objects that struck them in the early history of the solar system, right on down to the present. But planetary scientists have found that Venus underwent a colossal resurfacing event, a volcanic cataclysm, some three-quarters of a billion years ago.

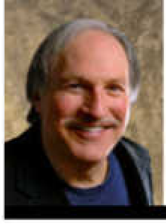
This means that most of the craters and other surface features we find on Venus are relatively young. But what could have caused such a huge, relatively recent global resurfacing? As one planetary scientist put it, "We are in the unenviable place of having to explain a planet that inexplicably threw up all over itself!"

For as yet unknown reasons, Venus seems to have stored enormous amounts of energy deep inside for a long time after the planet's formation. Scientists know that the better part of a billion years ago, a huge amount of this banked energy was released. But no one yet knows what triggered this event or why it happened exactly when it did.

Instabilities deep within Venus conspired — through physical evolution, the laws of physics, and interplay between countless atoms — to let loose and re-cover our "sister planet" in a large way. **— David J. Eicher**

A global view of Venus made with the Magellan radar mapper shows a multitude of surface features — all relatively young — on the hellishly hot planet.

NASA/JPL (VENUS); NASA/JPL-CALTECH (MARTIAN MILESTONE); NASA/LUNAR RECONNAISSANCE ORBITER (MOON SWIRLS); A. LONGOBARDI (MPE)/C. MIHOS (CASE WESTERN RESERVE)/ESO (GOBBLING GALAXY)



STRANGEUNIVERSE

BY BOB BERMAN

Do planets affect you?

Facing astrology with October's beautiful planetary lineup.

This month, all the naked-eye planets are crammed into one section of the zodiac. This busy freeway zone from Leo to Libra will look very cool. And it carries us to our topic: how the planets affect our lives.

The scene unfolds 45 minutes before sunrise. The action starts October 8 when from top to bottom stands a dramatic straight line composed of the Moon, Venus, Mars, Jupiter, and then Mercury down low. The next two mornings, the Moon floats smack among them. Then on the 11th, the hair-thin crescent Moon hovers next to Mercury.

The action resumes on the 16th, 17th, and 18th when Jupiter closely meets dim Mars with dazzling Venus above them and brightening Mercury below. A week later, Venus and Jupiter float rivetingly side by side. Add Saturn in the evening sky just two constellations over, and it's clear that all the naked-eye planets plus the Sun stand in the same general direction. Does this put the solar system out of balance like a badly loaded washing machine?

Well, when the heavyweights Saturn and Jupiter pull in the same direction, the Sun is physically yanked one Sun-width. As everything whirls around the solar system's barycenter, the Sun is therefore *not* currently in its average place in our sky. Can this planet business also affect *us*?

Massive Jupiter acts like a vacuum cleaner for asteroids and comets, deflecting them from hitting us. On the other hand, pieces of Mars do occasionally smash into Earth. Of the more than 52,000 known meteorites, 155 came from the Red Planet. So it is *possible* for Mars to kill you.

But unlikely. In the 20th century, only one person was ever hit by a meteorite, a stony asteroid fragment, so "the god of war" will probably not single you out for annihilation.

What about meddling with your everyday affairs? This brings us to astrology for the very first time. Nearly half of all Americans believe in it at least somewhat. Millions think the planets influence their romances, finances, and such. Does this ancient practice contain a germ of truth?

No. The topic fascinated me in the 1980s, which led to serious research and a formal broadcast debate with the editor of the *Larousse Encyclopedia of Astrology*. It also taught me a valuable lesson: When discussing astrology, never reveal your "sign." If you do, the conversation may go something like this.

MILLIONS THINK THE PLANETS INFLUENCE THEIR ROMANCES, FINANCES, AND SUCH.

Astrologer: "What's your sign?"

You: "I'm a Gemini."

Astrologer: "Whoa! You say you don't believe in astrology, but can't you see you're a perfect Gemini? There are twins inside you. You enjoy travel but also like to stay home. You like your freedom but also the security of a relationship. You have a split personality. You're a classic Gemini!"

And then you feel like a jerk, with no rebuttal. So instead, tell a little white lie. Now the conversation changes:

Astrologer: "What's your sign?"

You: "I'm a Taurus."

Astrologer: "Holy Toledo! Can't you see how you're a perfect Taurus? You're stubborn about science and inflexible about ancient wisdom — a classic Taurus personality!"

You: "I'm just kidding. I'm not a Taurus."

Astrologer (flustered): "You're not? Well, um, what's your real sign?"

You: "Scorpio."

Astrologer: "I knew it! The way you just tried to exercise power over our conversation. A control freak. You're a classic Scorpio."

You: "I lied. I'm not a Scorpio either."

At this point, you'd think the astrologer might question his craft, since you've effectively demonstrated how they make signs fit anyone. In practice, however, astrologers usually resist all forms of logic.

How can we be sure astrology is bogus? Countless studies. For example, astrology says that a person whose horoscope shows Mars in Aries is inclined toward a military career. So one study looked at 5,000 people who'd re-enlisted in the Marines. It would be unfair to demand they all have Mars in Aries. But if that concept has any meaning at all, that pattern would occur more than would be expected randomly. Turns out, just one in 12 Marines have Mars in Aries — exactly what's dictated by chance. Sadly, after studies such as this are published, the next astrology textbook editions continue with the same Mars/Aries/soldier business. Apparently, reality is of no interest to them.

One clever study even showed why astrology can *seem* to work. So if any reader is into it (you never know), well, have fun, but don't imagine it has any scientific support.

Despite all this, planets *can* influence your behavior. They'll make you get up before dawn this month, won't they?

Anyway, forgive this anti-astrology tirade. I can't help it. I'm an Aquarius, and we Aquarians tend to be skeptical.

Contact me about my strange universe by visiting **http://skymanbob.com.**

FROM OUR INBOX

Random chance?

In Jeff Hester's July column, he describes the design method of a truss and then suggests that the final design, judged to be superior to other designs, was developed by "accident," or random chance. That is not the case. The truss design was developed through an iterative design process, run by a computer program, that was given specific instructions by the programmer on both how to run successive iterations and how to judge which design was superior. To carry this forward to his evolution analogy would be to say that evolution is a design process developed and controlled by an intelligent being. I am OK with that. — **Tim Speer,** Midland, Texas

We welcome your comments at Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; or email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman.**

ASTRONEWS

SCHOOLBOY'S EXOPLANET. A British teen named Tom Wagg worked with an astronomer to comb through data from the Wide Angle Search for Planets, where he found the light dip of a planet orbiting a star 1,000 light-years away in the constellation Hydra.

LAUNCH FAILURE. SpaceX's Falcon 9 rocket broke up roughly two minutes after launch June 28, failing its mission to carry supplies to the International Space Station. This is the company's first failure after six resupply missions over the past three years and many more additional launch successes. NASA

SPACEX WINS AND LOSSES

On June 28, SpaceX attempted what was to be the company's seventh resupply mission to the International Space Station (ISS), only to have the unmanned vehicle break up just over two minutes after launch, resulting in total mission failure, the company's first. In a statement July 20, Elon Musk, SpaceX's CEO, attributed the Falcon 9 rocket's breakup to a strut that failed to meet force requirements, resulting in an overpressure event in the second-stage oxygen tank, though he declined to name the outside manufacturer and labeled this "an initial assessment."

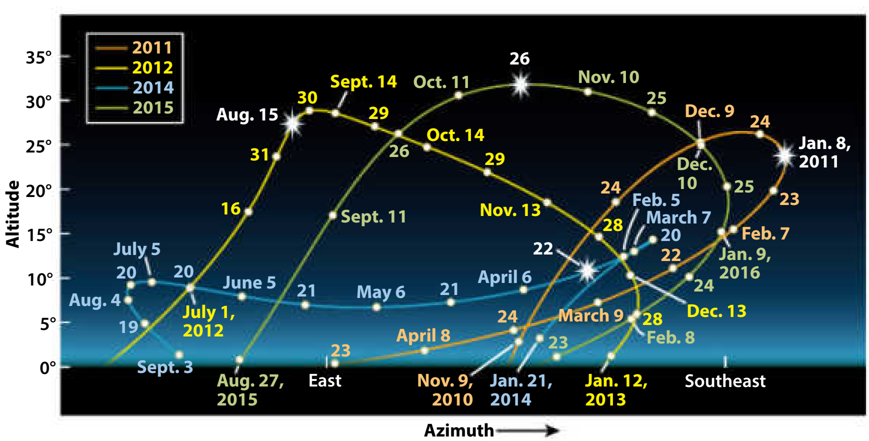
Six previous resupply missions had gone smoothly for the private space firm. On May 6, SpaceX also successfully tested its launch abort system — a sort of ejector seat for future crew. Additionally, the June 28 launch was meant to be the third attempt to land Falcon 9 on a drone barge — a bonus but so far unsuccessful objective — after launching the Dragon supply ship into orbit. While the rocket hit its target accurately on two previous landing attempts, it has been unable to land gently or upright enough to avoid destruction. SpaceX is striving for reusable rockets in order to drastically cut costs on future space launch missions.

Unfortunately, the SpaceX ISS resupply failure was the third such in eight months, starting with Orbital Sciences Corporation's Antares rocket malfunction last October and the Russian loss of its Progress capsule in April. The ISS still had supplies for several months, and further resupply missions occurred in July and August. Furthermore, several successful missions docked with the ISS in between the recent failures, including several SpaceX flights. — **Korey Haynes**

VENUS BEFORE DAWN

Venus won't be alone this October. At its peak on the 26th, Venus appears just 1.1° south of Jupiter, the night sky's second-brightest point of light.

FAST FACT



DAZZLING PLANET. It's hard to mistake Venus for any other celestial object. The brilliant point of light shines nearly 10 times brighter than Sirius, the night sky's brightest star, and three times more intensely than Mars or Jupiter at their best. But it truly stands out during October, when it climbs higher in the morning sky than at any other time this decade. This chart plots Venus' positions during its past four predawn apparitions for an observer at 40° north latitude an hour before sunrise. Notice that the planet's peak altitude often doesn't coincide with its greatest solar elongation (dates highlighted in white). *ASTRONOMY:* RICHARD TALCOTT AND ROEN KELLY

BRIEFCASE

GALACTIC SMOG

ALMA peered into the early universe, only a billion years after the Big Bang, to find the elusive signature of ionized carbon in early galaxies. Carbon likes to bond with other elements, so seeing carbon on its own in an ionized (highly energized) state is a strong sign that astronomers are looking at unevolved young galaxies that have not had time to form complex molecules. The new information, published June 25 in *Nature*, sheds light on how the early universe evolved.

•

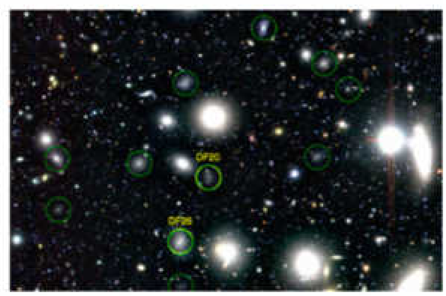
MARTIAN GLASS

Scientists using data from the Mars Reconnaissance Orbiter identified glass deposits around ancient craters on the Red Planet. The researchers, writing in *Geology*'s June issue, point out that on Earth impact glass can preserve valuable biosignatures from earlier eras, and the same could be true on Mars. That makes these glassy deposits prime targets for future sample exploration missions.

•

X-RAY ECHOES

Astronomers using the Chandra X-ray Observatory pinpointed the location of a neutron star system called Circinus X-1. The star is embedded in a thick shroud of gas and dust, obscuring the source. But, as reported in the June 20 issue of *The Astrophysical Journal*, scientists combined the different arrival times of X-rays echoing off these clouds with detailed radio images to home in on a distance of 30,700 light-years to the star. — **K. H.**



STAR-DEPRIVED GALAXIES. The Coma Cluster holds hundreds of "dark galaxies," which contain huge amounts of dark matter and a small number of stars. NAOJ

Dark galaxies abound in Coma Cluster

A shocking amount of dark matter likely surrounds more than 800 "dark galaxies" in the famous Coma Cluster, according to a study of archival data from Hawaii's Subaru Telescope. The galaxies are about the size of our Milky Way but contain only a fraction of the stars. In fact, stars make up just 1 percent or less of each galaxy's total mass and are generally from older stellar populations. This find follows a 2014 discovery of 50 other dark galaxies in the same cluster. That leads astronomers to believe clusters are prime environments for their formation. Scientists are now trying to understand what happened to all the gas that should have made stars. The study was carried out by astronomers at Stony Brook University and the National Astronomical Observatory of Japan and appeared July 1 in *The Astrophysical Journal Letters*. — **Eric Betz**

ASTRONEWS

CANNONBALL RUN. NASA supercomputer simulations show that strange warps in a debris disk around nearby young star Beta Pictoris might be caused by a planet smashing into dusty debris and creating spiral waves.

Black hole flares after 26 years of relative quiet

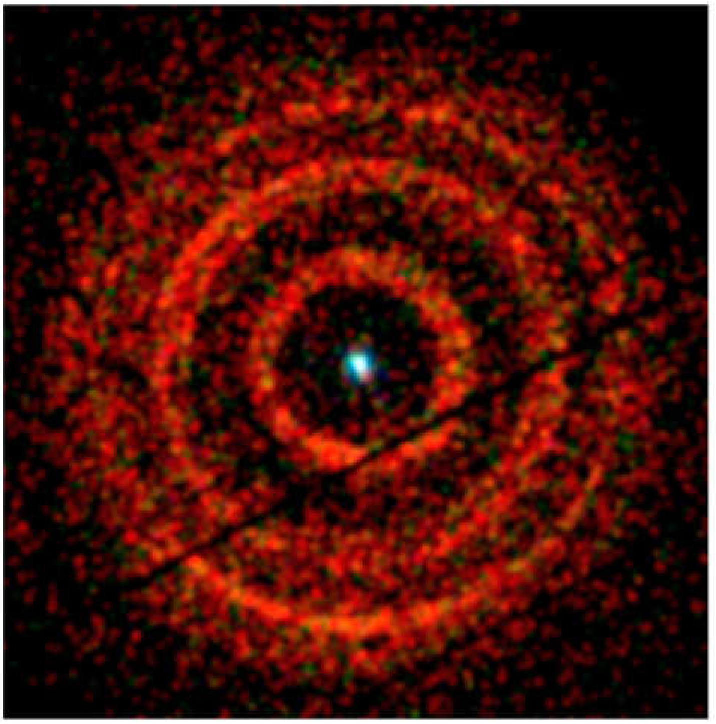
On June 15, the NASA Swift satellite's Gamma-ray Burst Explorer detected a bright X-ray flare coming from about 8,000 light-years away in the direction of the constellation Cygnus. This autonomous space observatory immediately broadcast the position of the outburst to other instruments around the world, and soon a major observing campaign in all wavelengths was on. What was happening? The low-mass X-ray binary V404 Cygni, which consists of a star slightly smaller than the Sun orbiting a black hole 10 times its mass, was having an episode, its first since 1989.

Every couple decades, V404 Cygni becomes an X-ray nova for a short period of time. In this binary system, the black hole slowly pulls a stream of gas from its stellar companion that gathers in a disk surrounding the black hole. Occasionally, though, the buildup of hot gas becomes too much, and the black hole gorges on the material, producing an episode of flares.

"The behavior of this source [was] extraordinary, … with repeated bright flashes of light on time scales shorter than an hour, something rarely seen in other black hole systems," says Erik Kuulkers, project scientist for the European Space Agency's Integral satellite, one of the many telescopes monitoring the outburst. "In these moments, it [became] the brightest object in the X-ray sky."

But it's more than just X-rays. In a single week after the initial flare, the Fermi Gamma-Ray Space Telescope's Gamma-ray Burst Monitor detected more than 70 gamma-ray flares from V404 Cygni, more than five times the number the instrument normally detects from all objects across the sky in the same time period. And according to observers, the X-ray nova is intriguing at all wavelengths.

"Relative to the lifetime of space observatories, these black hole eruptions are quite rare," says Neil Gehrels, Swift's principal investigator at NASA's Goddard Space Flight Center. "So when we see one of them flare up, we try to throw everything we have at it, monitoring across the spectrum, from radio waves to gamma rays." — **Karri Ferron**



X-RAY ECHO. The Swift satellite's X-Ray Telescope imaged the V404 Cygni X-ray binary system June 30, showing a series of rings. These represent an echo of X-ray light from a June 26 outburst of the binary's black hole. ANDREW BEARDMORE (UNIV. OF LEICESTER) AND NASA/SWIFT

Looking down on a celestial light show

NASA

ACTIVE AURORA. Severe geomagnetic storms rocked Earth in late June following successive plasma-packing coronal mass ejections that approached our planet from the surface of the Sun at some 780 miles (1,255 kilometers) per second. The perfectly aimed solar burps interacted with Earth's magnetic field and allowed skywatchers to glimpse aurorae as far south as Texas. The views captured by astronaut Scott Kelly flying 250 miles (400km) overhead on the International Space Station were even better. This image was among the many he shared. The strongest solar flare associated with the storms reached M7.9, which is still 10 times weaker than an extreme X-class flare. — **E. B.**

QUICK TAKES

LAZARUS EXOPLANET
NASA's Spitzer Space Telescope spotted a hot Jupiter unexpectedly glowing in infrared. Astronomers suspect it's been rejuvenated to look billions of years younger than it really is by grabbing material from its dead host star, a white dwarf.

SAUCER CRASH
NASA's future Mars cargo lander, the Low-Density Supersonic Decelerator, or "flying saucer," crashed into Earth's surface in a June test after its parachute failed once again.

DATING SATURN
Computer models show Jupiter is 4.5 billion years old but place still-warm and youthful Saturn a troubling 2 billion years younger. Sandia's Z Machine helped solve the problem in June by showing helium rain could heat the ringed world to hotter than expected levels.

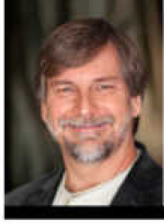
YOUTHFUL CLUSTER
Strange things are happening in a nearby star cluster called "Cloud D," which packs 1 million bright still-forming suns. For unknown reasons, some 7,000 of those are massive O-type stars — the universe's largest breed.

ASTEROID IMAGER
The first instrument for NASA's OSIRIS-REx mission to sample an asteroid was finished in June. The Thermal Emission Spectrometer is a microwave oven-sized camera built to map rocks and identify minerals.

CRATER CRUSADE
A team led by Canadian scientists trekked to the High Arctic in July to reach the recently discovered 28-mile-wide (45km) Tunnunik impact crater in hopes of understanding when it formed and what happened to life in the area.

PLUTO FLIGHT
On the eve of New Horizon's Pluto flyby, astronomers took to the skies in NASA's SOFIA Airborne Observatory to see the world occult a star.

ALIEN FORECAST
On June 24, Notre Dame astrophysicist Justin Crepp told a congressional panel that NASA's shelved Terrestrial Planet Finder could see all nearby Earth-like planets and their biomarkers within 20 years. — **E. B.**



FOR**YOUR**CONSIDERATION

BY JEFF HESTER

Intentional ignorance

Climate change deniers are trying to make NASA conveniently blind.

In the 1990s, NASA undertook an initiative called Mission to Planet Earth. The program would take the remote sensing techniques used to explore other planets and turn them on our home world. The plan virtually screamed "practical benefits."

By any measure, NASA's Earth science program has been an extraordinary success. It has revolutionized weather forecasts, agricultural predictions, resource management, and climate science. Return on investment is off the charts. But such a program has to be maintained. Quoting a 2007 report from the National Academy of Sciences, "The current capability to observe Earth from space is in jeopardy." Without resources, that capability will be lost.

So why is it that as of this writing, Congress is poised to slash as much as three-quarters of a billion dollars from the program and cripple a vital global perspective that we have come to depend on? The answer is disturbingly simple. Many in Congress, along with their well-heeled backers, would prefer that we not see what NASA's data are showing us.

The crux of the issue is, of course, global warming. But one thing that you *won't* often hear amid the hype on cable news is a calm, rational explanation of what global warming is and how it works.

Imagine a rock adrift in space. Energy arrives as visible sunlight, trying to heat things up. Energy leaves as thermal infrared radiation, trying to cool things down. At some temperature, the two will balance. Voilà! Now imagine the rock is wrapped in a blanket that lets sunlight in but makes it harder for infrared to get out. More energy is coming in than is leaving, so things heat up. Eventually, balance is restored, but at a new higher temperature.

The atmospheres of Venus, Earth, and Mars are just such blankets. Gases like carbon dioxide, water vapor, and methane are transparent to visible sunlight but block escaping infrared. The thin atmosphere of Mars only raises the temperature by about 9° F (5° C). The massive atmosphere of Venus heats the surface to a whopping 860° F (460° C), well above the melting point of lead!

Earth is the Goldilocks world. The so-called greenhouse effect raises Earth's average temperature from 33° F (18° C) *below* the freezing point of water to 27° F (15° C) *above* the freezing point of water. Without the greenhouse effect, George Lucas wouldn't have had to invent Ice Planet Hoth. He could have just used Ice Planet Earth instead!

Long before climate change became politicized, Astronomy 101 classes everywhere were doing this calculation. There was no controversy; it's simple physics. "OK," says the freshman business major taking the dreaded science course needed to graduate. "That means atmospheric carbon dioxide acts like a thermostat, right?"

"That's right," responds the professor, happy that somebody is paying attention.

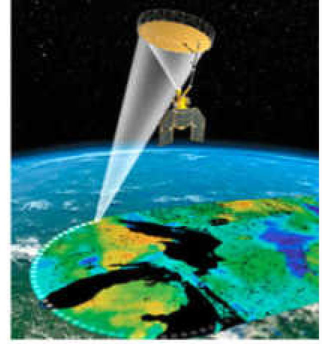
"So," our student continues, "if there were more carbon dioxide, Earth would be warmer, right?"

"Funny you should ask …"

Since 1750, humans have released over 300 billion metric tons of carbon into the atmosphere. There is 44 percent more carbon dioxide in our atmosphere today than there was before the Industrial Revolution. Half of that increase has come since 1980. There is over 30 percent more atmospheric carbon dioxide than at any time in the last 800,000 years. And just as our student realized, when you crank up the thermostat, things will start to heat up.

There are about a half dozen ways to measure Earth's thermal imbalance, and they all show that the planet is warming. Imagine Earth's surface covered by 1-kilowatt heaters, one every 100 feet (30 meters) or so. The heaters run 24/7, year after year, decade after decade: That is global warming.

Cable news will tell you there is scientific controversy about



NASA's newest Earth-sensing satellite, Soil Moisture Active Passive (SMAP), will supply information critical to groups ranging from farmers to disaster relief organizations — as long as it remains funded. NASA

this, but they misrepresent the facts. When 97 percent of the research in a field agrees, that's about as close to consensus as you are ever going to get, especially when there is a huge payday for *disagreeing*. Drexel University researchers found that between 2003 and 2010, $558 million from untraceable sources was funneled to climate change deniers.

Like organ grinders' monkeys, deniers do what they do. But as for serious people, according to the U.S. Navy's Military Advisory Board — hardly a liberal cabal — "Climate change impacts are already accelerating instability … and are serving as catalysts for conflict." Speaking for a bipartisan group of prestigious political, business, and academic leaders, former U.S. Treasury Secretary Robert Rubin summed it up well, calling climate change "the existential threat of our age."

While the details are subtle, the basics of global warming are incontrovertible and easily understood. It is disingenuous and irresponsible to pretend otherwise. Politicizing climate change is like politicizing gravity. If you step off of a building, you fall and hurt yourself, regardless of your politics. Crippling NASA's ability to observe Earth will not stop global warming; it will only leave us blind.

Jeff Hester is a keynote speaker, coach, and astrophysicist. Follow his thoughts at **jeff-hester.com.**

FROM OUR INBOX

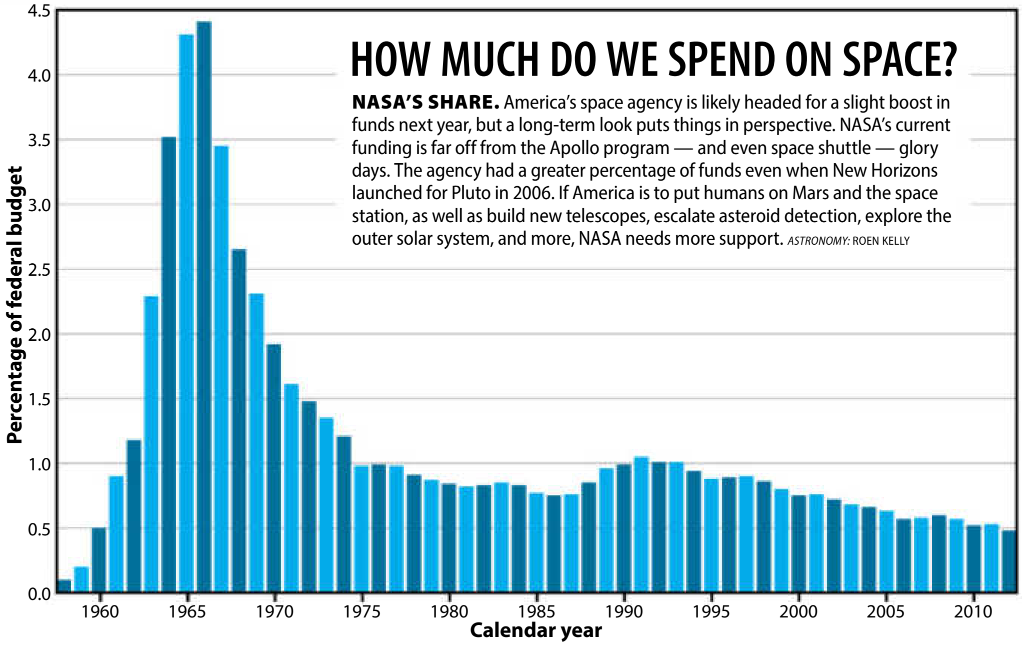
Great reads

Wow, what can I say, as a reader of *Astronomy* magazine since the late 1970s, I have to tell you that the May 2015 issue was one of the best I have seen. It had great articles on fighting to save Lick Observatory (p. 46), touring the Herschel Museum (p. 62), and Starmus 2014 (p. 54). Then you followed it up with the June issue that had an excellent interview with Jim Lovell (p. 24) — that was just icing on the cake! — **Jim Olivero,** Sparks, Nevada

BROWSE THE "FOR YOUR CONSIDERATION" ARCHIVE AT **www.Astronomy.com/Hester.**

EXILED STARS. Astronomers used crisp Hubble images of supernovae seen several years ago to confirm the stars exploded far from their home galaxies, having been thrown hundreds of light-years into intergalactic space.

HOW MUCH DO WE SPEND ON SPACE?



NASA'S SHARE. America's space agency is likely headed for a slight boost in funds next year, but a long-term look puts things in perspective. NASA's current funding is far off from the Apollo program — and even space shuttle — glory days. The agency had a greater percentage of funds even when New Horizons launched for Pluto in 2006. If America is to put humans on Mars and the space station, as well as build new telescopes, escalate asteroid detection, explore the outer solar system, and more, NASA needs more support. *ASTRONOMY:* ROEN KELLY

Congress boosts funds for "ocean worlds," SLS

The U.S. House of Representatives voted to increase NASA funding for a new program to explore the solar system's ocean worlds in June but cut funding to study our own.

The president's 2016 NASA budget had asked Congress to approve \$18.5 billion for the space agency. His proposal included a significant increase for the commercial crew program that's working toward privately contracted space taxis to deliver supplies and astronauts to the space station.

The House approved the president's funding level but shifted the money around. The bill instead would cut the commercial crew program by \$240 million, which NASA Administrator Charles Bolden says will delay America's ability to send humans to low Earth orbit.

Some Republicans also have criticized NASA's focus on Earth sciences, saying the space agency should look out and not in. As it sits, the bill cuts \$90 million from those efforts and denies funds for a new Earth-observing spacecraft.

Instead, the Republican-backed legislation puts the money cut from commercial crew and Earth science into other areas. That includes a mission to Europa and a more than \$500 million increase above the president's request for NASA's Space Launch System (SLS). The rocket will be the largest ever built and could carry humans beyond low Earth orbit. Congress also wants NASA to use SLS to launch Europa Clipper as early as 2022, which is earlier than previously planned and on a rocket that would take it to Jupiter faster.

The Planetary Society, Bill Nye's nonprofit group that advocates for space exploration, expressed support for the increased funds given to planetary science and astrophysics, as well as concern over cuts.

"I feel that this bill perfectly demonstrates the problem currently dogging NASA: the nation is asking for a \$24 billion space program in an \$18.5 billion budget," Casey Dreier, the group's advocacy director, wrote online.

At press time, the bill was held up awaiting the Senate's version before going to the president. — **E. B.**

140 million Suns The mass contained in the supermassive black hole at the heart of distant spiral galaxy NGC 109, according to a study published online June 5 in *The Astrophysical Journal.*

Rosetta spies sinkholes on a comet

Circular pits on Comet 67P/Churyumov-Gerasimenko have puzzled scientists since the European Space Agency's Rosetta spacecraft first approached. Images also show dust and gas streaming from the sides of these pits, and astronomers now think they've identified the regions as sinkholes, similar to those found on Earth. On Comet 67P, they form when a heat source underneath the surface causes water, carbon monoxide, and carbon dioxide ices to sublimate, or turn directly from solid to gas. This leaves a subsurface cavern, and eventually the unsupported ground collapses, leaving the steep holes observed by Rosetta. — **K. H.**

COMET COLLAPSE. Seth-01 is the most active pit currently observed on Comet 67P/Churyumov-Gerasimenko, and scientists now suspect it could be a sinkhole. VINCENT ET AL., NATURE PUBLISHING GROUP

WHERE IT ALL BEGAN. This artist's impression shows the brilliant Population III stars that made up the first generation of the universe's stellar inhabitants. ESO/M. KORNMESSER

First generation of stars found

Astronomers using a collection of world-class telescopes from the ground and space found the brightest galaxy so far in the early universe, which may contain the very first generation of stars. The work has been accepted for publication in *The Astrophysical Journal*.

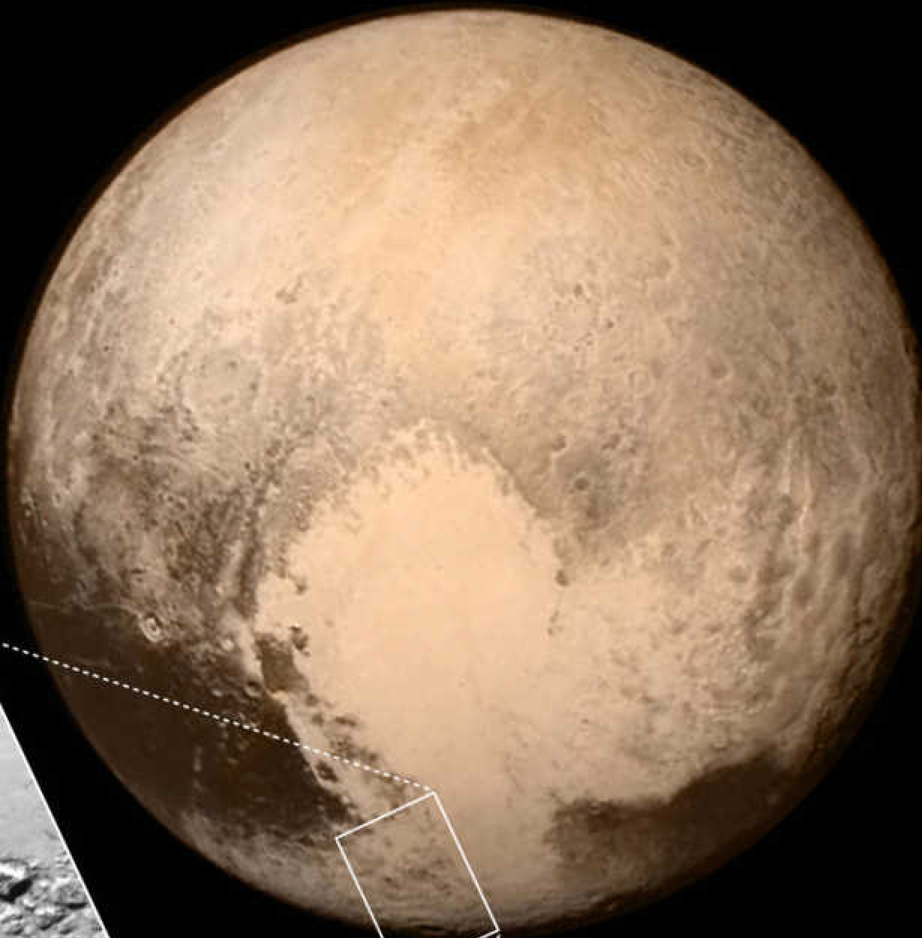
Stars are factories for turning the light elements of hydrogen and helium into heavier ones like carbon, oxygen, and every other naturally occurring element (commonly called "metals"). While all stars are mostly hydrogen and helium, modern stars (known as Population I) also contain at least trace amounts of metals (older, even less metal-rich stars are known as Population II). But if these metals were created in the belly of a previous star, then somewhere near the beginning of the universe must have existed a population of stars containing nothing but the hydrogen, helium, and trace amounts of lithium created immediately after the Big Bang. Until now, this starter group, known as Population III stars, has existed only in theory.

Population III stars should have been massive, blazing-hot monsters that exploded as supernovae after only 2 million years or so. While looking at their super-bright early galaxy, astronomers observed strong emission from ionized helium but no signs of any heavier elements — exactly what they would expect from the first generation of stars. — **K. H.**

PLUTO COMES INTO FOCUS

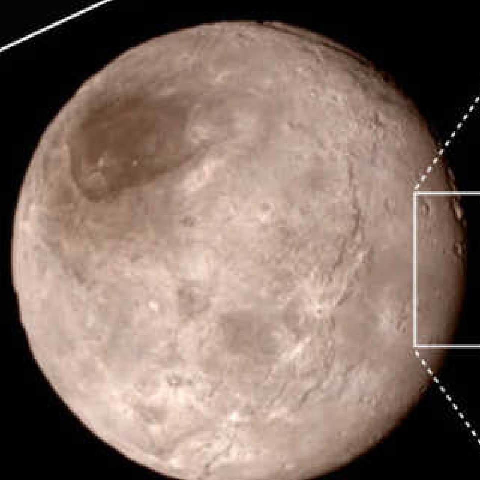
A JOURNEY 3 BILLION MILES (5 billion kilometers) in the making came to its pinnacle July 14 as NASA's New Horizons spacecraft zoomed past Pluto and its system of moons, collecting hundreds of observations that it will gradually relay to Earth over the next year.

In only the first week after closest approach, scientists had already discovered that this system has lots of surprises in store for them, including worlds even more geologically active than they had anticipated. These views, which are highly compressed for quicker transmission, provide a sneak peek of the excitement still to come. — **K. F.**



THE HEART OF THE MATTER

All eyes were on the heart-shaped region of Pluto's surface when New Horizons scientists released this single full-disk composite of the dwarf planet captured July 13, 2015. The area, informally named Tombaugh Regio after Pluto's discoverer, spans some 1,000 miles (1,600km) and is intriguing for its lack of craters. Near its edge, as shown in this first close-up view that spans some 150 miles (240km), is a mountain range with icy peaks reaching as high as 11,000 feet (3,500 meters) above the surface. Scientists believe the range, informally named Norgay Montes after one of the first people to climb Mount Everest, formed no more than 100 million years ago.



CHARON SURPRISES

Pluto's largest moon came into clear view July 13, 2015, in this full-disk composite image captured just hours before New Horizons' closest approach the following day. Charon surprised mission scientists with its relatively youthful and varied terrain. Many intriguing features are visible here, including a thin deposit of dark material on the moon's north polar region (upper left in this view), a range of cliffs stretching 600 miles (1,000km) across the world's midsection, and relatively few craters. In the first close-up image delivered by New Horizons, which runs about 240 miles (390km) from top to bottom, mission scientists even discovered a depression with a strange peak in the middle (upper left in the inset).

ALL IMAGES: NASA/JHUAPL/SwRI

ASTRO**CONFIDENTIAL**

WHAT ARE WE LEARNING ABOUT HOT JUPITER ATMOSPHERES?

Korey **Haynes**
Associate editor at *Astronomy* magazine, George Mason University Ph.D. graduate, and former researcher at NASA's Goddard Space Flight Center

Hot Jupiters are the biggest, brightest exoplanets out there, which makes them great targets for characterization work — finding out what they're made of, how hot they are, and how their atmospheres are structured. One way to do this is by looking at an exoplanet's spectrum — its chemical fingerprint — just before, during, and after it crosses behind its star, which lets us compare the star + planet light to the light emitted from just the star. The difference between the two is the light emitted by the planet itself, specifically its day side.

The relatively new Wide Field Camera 3 (WFC3) on the Hubble Space Telescope has a spectrometer that, while not designed for exoplanet work, can nonetheless reveal amazing details about these worlds' atmospheres. It operates in the infrared, at a region where there's a very strong signature for water, which, regardless of its importance to humans, is actually a simple substance we expect to see forming easily in these planets. By studying this signal's shape and strength, we learn about the temperatures of different layers of the planet's atmosphere.

In the case of hot Jupiter WASP-33b, we used WFC3 to learn that it has a stratosphere, a layer that gets hotter with altitude instead of cooler, like most layers. Ozone causes a stratosphere on Earth by absorbing radiation and heating up. But ozone can't exist in the extreme environment of WASP-33b. Instead, the temperature flip is caused by a hardier substance, titanium oxide, performing the same job. And not only did we measure a hotter upper layer, but we also saw spectral evidence for titanium oxide itself, which really pulls together the story of this planet's atmosphere in a way that hasn't been possible until now.


ASTRONOMY: WILLIAM ZUBACK

WASP-33b is one of the hottest known exoplanets, at 5,700° F (3,100° C). FAST FACT

ASTRO**NEWS**

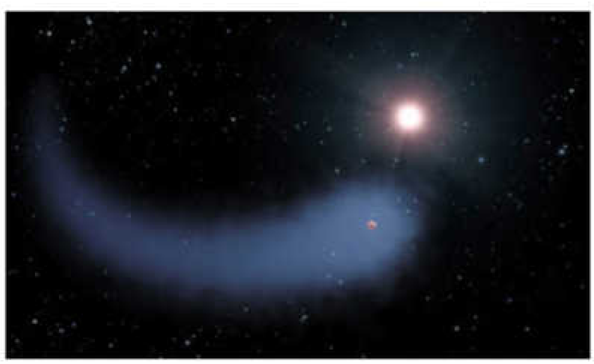
SQUEAKY WORLDS. Warm Neptune-sized planets seen orbiting close to their host stars might have helium atmospheres unlike anything in our solar system, say astronomers trying to explain Spitzer Space Telescope data.


NASA/ESA/D. CALZETTI (UMASS)/H. FORD (JHU)/THE HUBBLE HERITAGE (STScI/AURA)-ESA/HUBBLE COLLABORATION

Colorful galaxy lost in space

EDGE OF DARKNESS. The spiral galaxy NGC 6503 lurks at the edge of the Local Void, a nearby empty region of space 150 million light-years across. The Hubble Space Telescope captured this image of the "Lost in Space Galaxy," as it is sometimes known, with multiple filters. Red shows gas while blue reveals young stellar regions. Dark brown shows where thick dust lanes block background light. The galaxy is approximately a third of the size of the Milky Way. — **K. H.**

Comet-like tail seen streaming from Neptune-sized exoplanet



TALE OF A TAIL. Scientists have uncovered a nearby Neptune-sized exoplanet with a huge comet-like tail of hydrogen, as seen in this artist's concept. The extreme radiation of the red dwarf host star is causing the element to escape from the planet. NASA/ESA/G. BACON (STScI)

When scientists look at the 2004 exoplanet discovery GJ 436b in visible light, they see a Neptune-sized world orbiting extremely close to its red dwarf parent star in just 2.6 Earth days. Strange, indeed, seeing a 23-Earth-mass world less than a tenth of the Mercury-Sun distance from its star. But GJ 436b's truly weird nature only recently came to light when astronomers trained the Hubble Space Telescope's ultraviolet eye on the planetary system, revealing a massive cloud of hydrogen about 50 times the circumference of the star streaming off the exoplanet. The observations appeared in the June 25 issue of *Nature*.

"This cloud is very spectacular," says study lead David Ehrenreich of the Observatory of the University of Geneva in Switzerland. "It's as if, after carrying the planet's atmosphere [to] a high temperature, causing the hydrogen to evaporate, the radiation of the star was too weak to blow away the cloud that accumulated around the planet."

Scientists have never seen such a high amount of atmospheric escape from an exoplanet before, and Ehrenreich and his colleagues estimate that the cloud may represent 10 percent of GJ 436b's atmosphere. Such a process could explain how hot super-Earths — rocky worlds larger than our planet orbiting close to their parent stars — form; they could just be hot Neptunes that lost their atmospheres. — **K. F.**

OBSERVING**BASICS**

BY GLENN CHAPLE

Understanding brightness

The Helix Nebula provides a lesson in how size changes everything.

One of the first concepts the novice backyard astronomer needs to grasp is the idea of magnitude. The magnitude of a star defines its brightness and, therefore, its visibility. It's easy to understand once you get used to the idea that the *larger* the magnitude number, the *fainter* the star. Although the brightnesses of clusters, nebulae, and galaxies are also expressed in magnitude, the numbers are deceiving. The Helix Nebula (NGC 7293) in Aquarius is a case in point.

Back in the early 1970s when I was a fledgling skygazer, I was thumbing through a sky guide seeking targets for my 3-inch reflector. I came across a listing for the Helix Nebula, described as a 7th-magnitude planetary nebula. "Piece of cake," I thought as I set up my scope. I centered the finder on the nebula's location less than 1½° west of the 5th-magnitude star Upsilon (υ) Aquarii and peered into the eyepiece. Nothing! A lengthy search with different magnifications failed to do the trick. Was something wrong with the telescope or my eye?

As it turns out, the telescope was just fine. So was Chaple (at least visually). The Helix Nebula is 7th magnitude, but unlike a 7th-magnitude star, which is a point source, NGC 7293's light spreads out over an area about 15' across. Center a 7th-magnitude star in the eyepiece field, defocus it until it's half the Moon's apparent diameter, and you'll have a hard time seeing anything! This is why the Helix, despite being one of the brightest planetary nebulae, is also one of the most elusive. Even William Herschel failed to capture it during his all-sky surveys of the late 18th century. No surprise, because the Helix is actually easier to see with binoculars and small rich-field telescopes than it is through high-power instruments like the huge reflecting telescopes Herschel used.

Knowing what I was up against, I returned to the Helix Nebula in the summer of 1981. Through the same 3-inch scope I had used during that ill-fated first attempt, I could make out something large, faint, and circular. To be sure I wasn't hallucinating, I asked a friend nearby to confirm my sighting. He saw it, too. Gotcha, Helix!

Why was I successful this time? For one thing, my eyes were better trained. A decade at the telescope made sure of that. The night was clear (absolutely no haze) and moonless, and my observing site was in a rural area far from any light pollution. It also provided an open southern horizon free of sky glow because the Helix is "way down there" at –21° declination. I used a low-power eyepiece (one that gave a 1° field of view in my scope to capture the Helix against a dark background) and didn't even begin the search until I had allowed my eyes about 15 minutes to dark adapt.

Despite glowing at 7th magnitude, the Helix Nebula (NGC 7293) can be tough to spot because its brightness spreads over a large area. HUNTER WILSON

Try this strategy, and if all goes well, you'll come face-to-face with the same phantom-like glow that greeted my eyes. With a medium- to large-aperture scope, you might even discern its annular form.

Last month, I commented on the fact that a majority of deep-sky objects show up telescopically as either starlike specks or faint fuzzies. The Helix Nebula is a "faint fuzzy" to the extreme — definitely not a visual "wow" object. We need to learn more about it to conjure up an intellectual "wow!"

We begin by traveling about 12,000 years back in time and some 650 light-years into space to a dying star. In its lifetime, it was similar in mass and size to our Sun. But with its hydrogen fuel depleted and its core collapsing, it has begun shedding its outer layers as an expanding envelope of gases.

Flash forward to the present, and these gases are still rushing outward at a speed of up to 16 miles (25 kilometers) every second. The tube-shaped envelope is now nearly 3 light-years across — more than two-thirds the distance between us and the star Alpha (α) Centauri. In its center, visible as a 13th-magnitude sun, is all that remains of the once vibrant star. About the size of Earth but with much of the mass of the original star, it's a white dwarf so dense that a spoonful of its matter weighs several tons. Wow!

The Helix Nebula offers three visual challenges. Can you capture it through binoculars or a small telescope? What's the smallest aperture with which you can discern its annular form? What's the smallest aperture that allows you to spot its 13th-magnitude central star?

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: A star-hop in Aries. Clear skies!

FROM OUR INBOX

Intelligent design

Jeff Hester's July 2015 article, "It's genetic" (p. 10), carried a powerful but subtle message. I was very surprised to see such a compelling argument for "intelligent design."

Now we know that the random appearance of changes in DNA structures are actually the result of a great intelligence (in this case, software) deciding what designs stay and what designs are discarded.

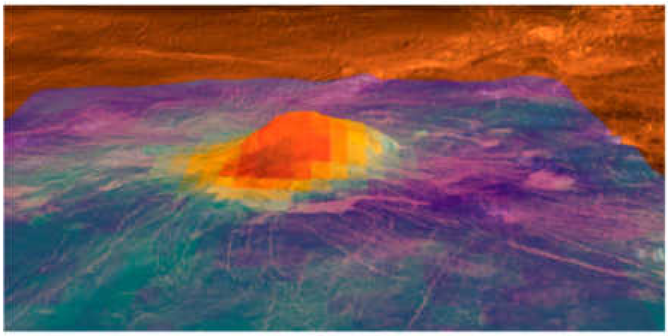
I am reconsidering my opinion of intelligent design.

— **Sam Johnson,** Frederick, Maryland

The key thing to understand is that the only "intelligence" employed by the computer is that of a random number generator. The fact that 1+1=2 is a simple statement of logic. So is the statement that populations subject to inheritance with variation and selection based on merit will evolve over time. The remarkable thing is that whether run on a computer or in DNA, blind, unguided logic accomplishes extraordinary things without the need for intelligence or design at all. — **Jeff Hester,** Contributing Editor

BROWSE THE "OBSERVING BASICS" ARCHIVE AT **www.Astronomy.com/Chaple.**

ASTRONEWS



ACTIVE ERUPTIONS. Before it ran out of fuel, the European Space Agency's prolific Venus Express spacecraft detected active hot spots near volcanic regions like Idunn Mons, a venusian volcano. ESA/NASA/JPL

Venus Express finds lava flows

The European Space Agency's Venus Express spacecraft met a fiery demise in 2014 following an eight-year observing run, but not before returning the best evidence so far for active volcanoes on Earth's toasty twin. The planet is just slightly smaller than our own and made from similar materials, yet its thick veil of clouds makes it tough to understand the surface.

Astronomers have long theorized that Venus turned inside out about half a billion years ago, completely resurfacing the world in a cataclysmic flood of lava. But does lava still flow on the surface? Venus Express was built partly to probe the planet for an answer.

In 2010, mission scientists noticed several volcanic regions were hotter than surrounding terrain but couldn't definitively say if the eruptions were more recent than a few million years ago. But Venus Express had another clue — sulfur dioxide peaked in the upper atmosphere in 2006 and then fell off over the following five years. One final find sealed the case.

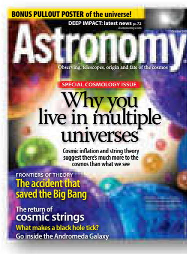
The craft's Venus Monitoring Camera (VMC) used infrared light to pierce the clouds and see volcanoes heat up drastically and then cool down over several days. In all, VMC picked up four hot spots in tectonic rift zones — areas of upwelling subsurface magma — near the volcanoes Ozza and Maat Mons.

The study was published in June in the journal *Geophysical Research Letters* after astronomers completed their analysis of data from the deceased spacecraft.

"These observations are close to the limits of the spacecraft's capabilities, and it was extremely difficult to make these detections with Venus' thick clouds impairing the view," says the instrument's principal investigator, Wojciech Markiewicz of the Max Planck Institute for Solar System Research. "But the VMC was designed to make these systematic observations of the surface, and luckily we clearly see these regions that change in temperature over time and that are notably higher than the average surface temperature." — **E. B.**

25 years ago in *Astronomy*

In October 1990, Timothy Dowling reviewed the Voyager probe's newest discoveries on Uranus and Neptune. Between the two blue ice giants, the mission observed complex ring and moon systems, thick methane clouds, and curious magnetic fields.



10 years ago in *Astronomy*

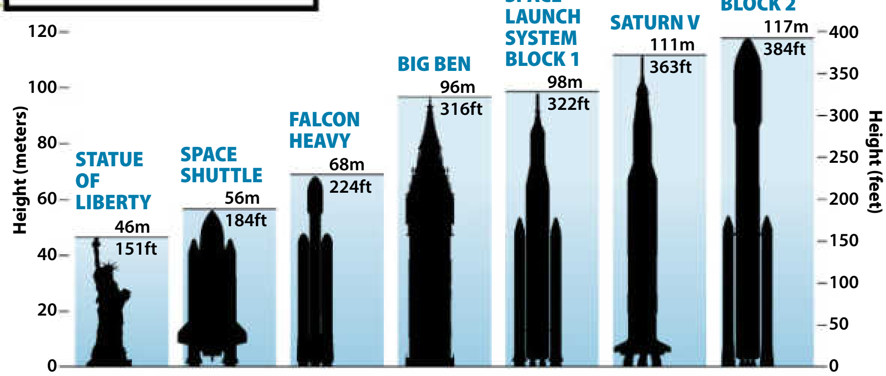
In the October 2005 issue of *Astronomy*, Senior Editor Richard Talcott reported on the Deep Impact mission that smashed into Comet 9P/Tempel on July 4 of that year. Now Rosetta, currently orbiting Comet 67P, has picked up the baton of comet lessons. — **K. H.**

BIGGER IS BETTER

FAST FACT

Space Launch System's Block 2 configuration will have a payload capacity of 143 tons.

BLAST OFF. Compare the size of past, present, and future rocket heights to some well-known landmarks. Bigger rockets allow bigger payloads, and humans have a lot of stuff we'd like to put into space.



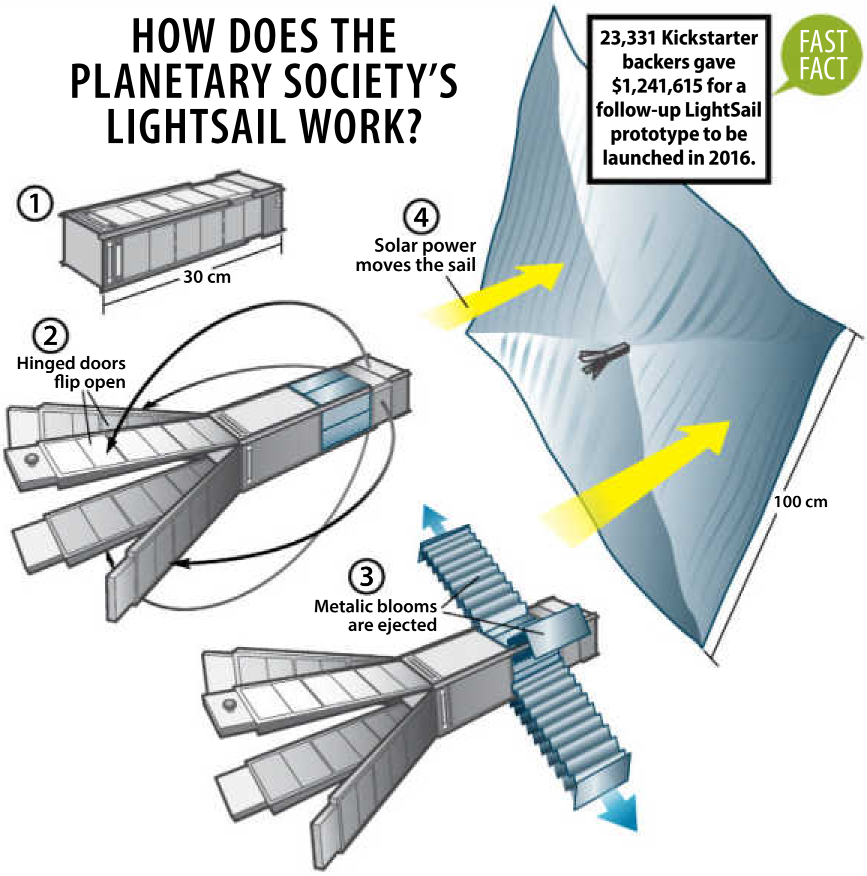
ASTRONOMY: ROEN KELLY AND KOREY HAYNES

QG

ASTRONEWS

FIRE AND BRIMSTONE. Researchers used copper isotopes and meteorites to trace Earth's geochemical evolution and found that its core contains 10 times the amount of sulfur as the rest of Earth combined, roughly 8.5×10^{18} tons.

HOW DOES THE PLANETARY SOCIETY'S LIGHTSAIL WORK?



CHEAP RIDE. LightSail had a rocky mission start in May, reaching Earth orbit only to lose contact with Earth. But The Planetary Society regained control of its craft in early June and successfully deployed its solar sail, providing a proof of concept for an even more ambitious LightSail to be launched on SpaceX's Falcon Heavy rocket next year. By moving away from chemical propulsion, the group hopes to significantly reduce the cost of traveling in our solar system. Electromagnetic radiation — light — exerts a constant but weak force on everything it hits. As photons bounce off the reflective surface of a sail, they give it a tiny bit of their momentum, gradually pushing a craft faster than traditional propulsion. *ASTRONOMY:* ERIC BETZ AND ROEN KELLY

GALACTIC MAGNETISM. Galaxy IC 342 is seen here in at optical and radio wavelengths, with yellow lines showing the orientation of magnetic field lines.

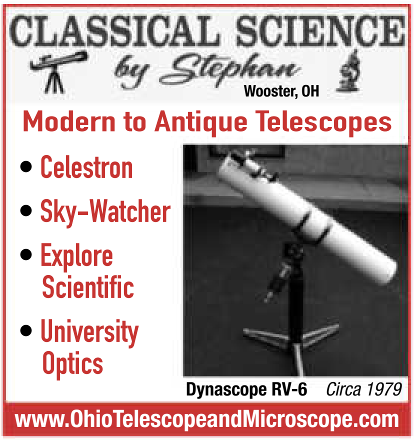
R. BECK (MPIFR)/NRAO/AUI/NSF/U. KLEIN (AIFA)/T. A. RECTOR (UNIV. ALASKA ANCHORAGE)/H. SCHWEIKER (WIYN)

Magnetic fields trace galaxy evolution

Astronomers using the Very Large Array in New Mexico and the Effelsberg 100-meter radio telescope in Germany mapped for the first time a magnetic field coiled around a galaxy's spiral arm. The team published their results in the June *Astronomy & Astrophysics*.

IC 342 is the third-closest spiral galaxy to Earth and is located in the constellation Camelopardalis the Giraffe. By observing the polarization of radio waves at several different frequencies, astronomers were able to map the galaxy's magnetic field lines, which are oriented perpendicular to the direction of polarization.

The strength of the lines is enough, the team reports, to affect the flow of gas in the galaxy's spiral, meaning that magnetism, in addition to gravity, plays a role in determining the galaxy's shape and evolution. The magnetic lines also point to a central black hole where gas is swirling in, supporting the galaxy's high rate of star formation seen in other observations. — **K. H.**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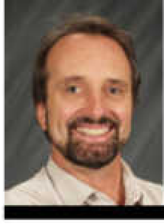


SECRET**SKY**

BY STEPHEN JAMES O'MEARA

The doppelgänger effect

Two Suns are better than one!

Here's a good one for the month that includes Halloween. Last May, my fiancee, Deborah Carter, and I were on Mauna Kea, Hawaii, just below the summit and its splash of telescopes. We stood on the shore of Lake Waiau in the rarified air at 13,000 feet (4,000 meters) altitude. The Sun was near setting, and as Deborah enjoyed a moment of solitude gazing into the lake, I sauntered off to take in the Mars-like terrain. On my return, Deborah looked perplexed, telling me of a weird phenomenon she observed.

"As I gazed into the lake, I felt a need to look behind me. At first I saw a dark line in the earth above my shadow and wondered what it was," she later said. "I thought perhaps it was a fissure. So, I decided to walk over and see it, but when I moved, it also moved. I was overcome with a feeling of not being alone, that there was a 'presence' there, that I was being watched. I stopped in my tracks. All of this happened in a matter of seconds. Then I moved again and logic kicked in, and I thought that it was a second shadow but wondered how it was being made. Then the second shadow disappeared."

Shadow people

After hearing Deborah's account, I scanned the terrain and at first saw nothing out of the ordinary. Our shadows were long and thin, as you would expect from a low Sun. But I didn't see a second shadow. When I walked away from a distant patch of rocks, however, I noticed a faint dark streak on the ground. It lay well above my shadow, and it followed me. When I raised my arm, so, too, did my shadow and the "streak."

This image shows the dark shadows of the author and his fiancee. Above them, you can see the much fainter doppelgänger shadows. DEBORAH CARTER

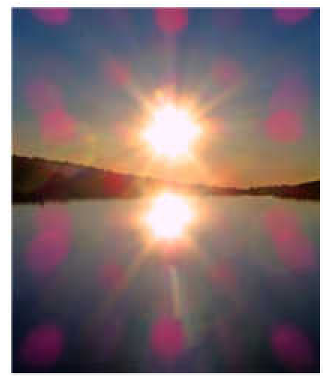
When Deborah saw this again, something clicked. She turned around and found the solution: The Sun shining over our shoulders was creating our normal shadows. And an image of the Sun reflecting off the lake's surface allowed the second shadow to form.

Being lower than our bodies, the Sun's dimmer reflection projected a new set of fainter shadows higher up onto the wall of the rocky depression we were in. Two Suns equaled two shadows. For a moment, I felt like I was standing on an alien world orbiting a binary star.

After giving the phenomenon some thought, I decided to call it the doppelgänger effect. The word comes from the German *doppel* (double) and *gänger* (walker or goer). It commonly describes someone who looks exactly like another person, but it also refers to an apparition in the shape of a person — as in the twin shadow we saw.

A "hollow" phenomenon

Just before sunset, I observed another curious phenomenon related to the first. Tall rocks and grasses in my normal shadow shone brightly through it, causing it to glow and look hollow. Deborah also saw this before the effect vanished once the Sun's reflection disappeared.



Although overexposed, this image reveals the reason for the twin shadows — the actual Sun and its reflection in a lake. DEBORAH CARTER

This complementary effect is similar to fill-flash in photography — a technique that uses a flash to illuminate details hiding in the shadows of an otherwise bright image. In the case at Lake Waiau, the reflected Sun served as the flash. As soon as the image vanished, our single shadow no longer looked hollow.

As always, send what you see and think to sjomeara31@gmail.com.

COSMIC WORLD

A look at the best and the worst that astronomy and space science have to offer. **by Eric Betz**

Cold as space ← → Supernova hot

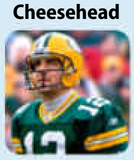
Observer bias

The Syfy channel launches TV space opera *Dark Matter* based on a comic about astronauts who awaken in space with their memories wiped. Earthly audiences wish for the same procedure.

Splash down

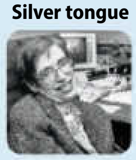
NASA's "flying saucer," designed to land heavy payloads on Mars, crashes (again) after failing to fully deploy its parachute. They'll try holding tests somewhere other than Roswell next time.

Cheesehead



Green Bay Packers quarterback Aaron Rodgers beats astronaut Mark Kelly at *Celebrity Jeopardy*, netting $50,000 toward charity. Bears fans move to send him on NASA's next year in space.

Silver tongue



An audience question prompts Stephen Hawking to suggest brokenhearted teens seek solace in theoretical physics after Zayn Malik leaves the band One Direction. In an alternate universe, he never left.

SYFY/BEN MARK HOLZBERG (OBSERVER BIAS); NASA/JPL-CALTECH (SPLASH DOWN); MIKE MORBECK (CHEESEHEAD); NASA GSFC (SILVER TONGUE)

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OBSERVING TOOLS

Fall observing videos

As temperatures drop and nights get longer, great targets appear in the sky, and *Astronomy*'s editors can help you find the best with our seasonal observing videos. Senior Editor Michael E. Bakich gears one video toward beginning observers and easy targets. In another, he focuses on objects you can see through a small telescope, such as the Andromeda Galaxy (M31) and the Double Cluster (NGC 869 and NGC 884). And in a third video, Editor David J. Eicher shares 10 of his favorite fall deep-sky objects, including Stephan's Quintet. Check out them all at **www.Astronomy.com/seasons**.

COMMUNITY

Reader Photo Gallery

Browse thousands of beautiful astroimages like this one of the Hamburger Galaxy (NGC 3628) by Bruce Waddington. Submit your own images at **www.Astronomy.com/readergallery**.

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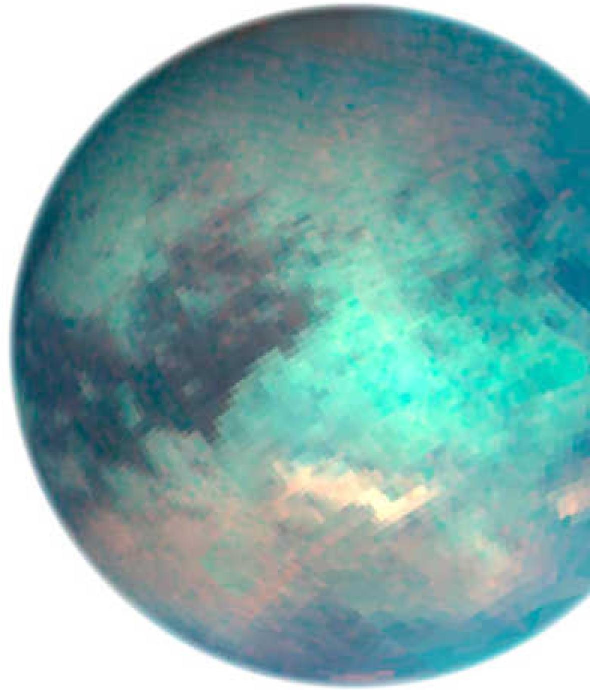
Secrets from Titan's seas



These images show Titan, from left to right, in October and December 2005 and January 2006. The view from December is roughly the opposite side of the moon from the October and January flybys, but careful inspection of Titan's polar regions shows how dynamic and variable the polar weather can be. NASA/JPL/UNIVERSITY OF ARIZONA

By probing "magic islands" and seafloors, astronomers are learning more than ever about the lakes and seas on Saturn's largest moon. **by Alexander G. Hayes**

IMAGINE YOURSELF standing at the shoreline of a picturesque freshwater lake, surrounded by soft grass and leafy trees. Perhaps you are enjoying a peaceful lakefront vacation. In the calm water, you see the mirror-like reflection of a cloudy sky just before it begins to rain. Now, let the surrounding vegetation disappear, leaving behind a landscape you might more reasonably expect to see in the rocky deserts of the southwestern United States. The temperature is dropping too, all the way down to a bone-chilling –295° F (92 kelvins). The air around you feels thicker, although you yourself feel seven times lighter, courtesy of reduced gravity. As the clouds pass overhead, you notice that the lake surface now reflects a hazy orange sky with the brightness of early twilight. After the clouds have moved on, you finally begin to feel rain hitting your hands. However, the rain falls much slower than normal and the drops are bigger, with large splashes following each impact. The ground you stand on is a loose sandy mixture of broken-up water ice and organic material like plastic shavings or Styrofoam beads. On closer inspection, the lake holds not water, but a liquid not unlike natural gas. And you'd better be holding your breath because the surrounding air has no oxygen.

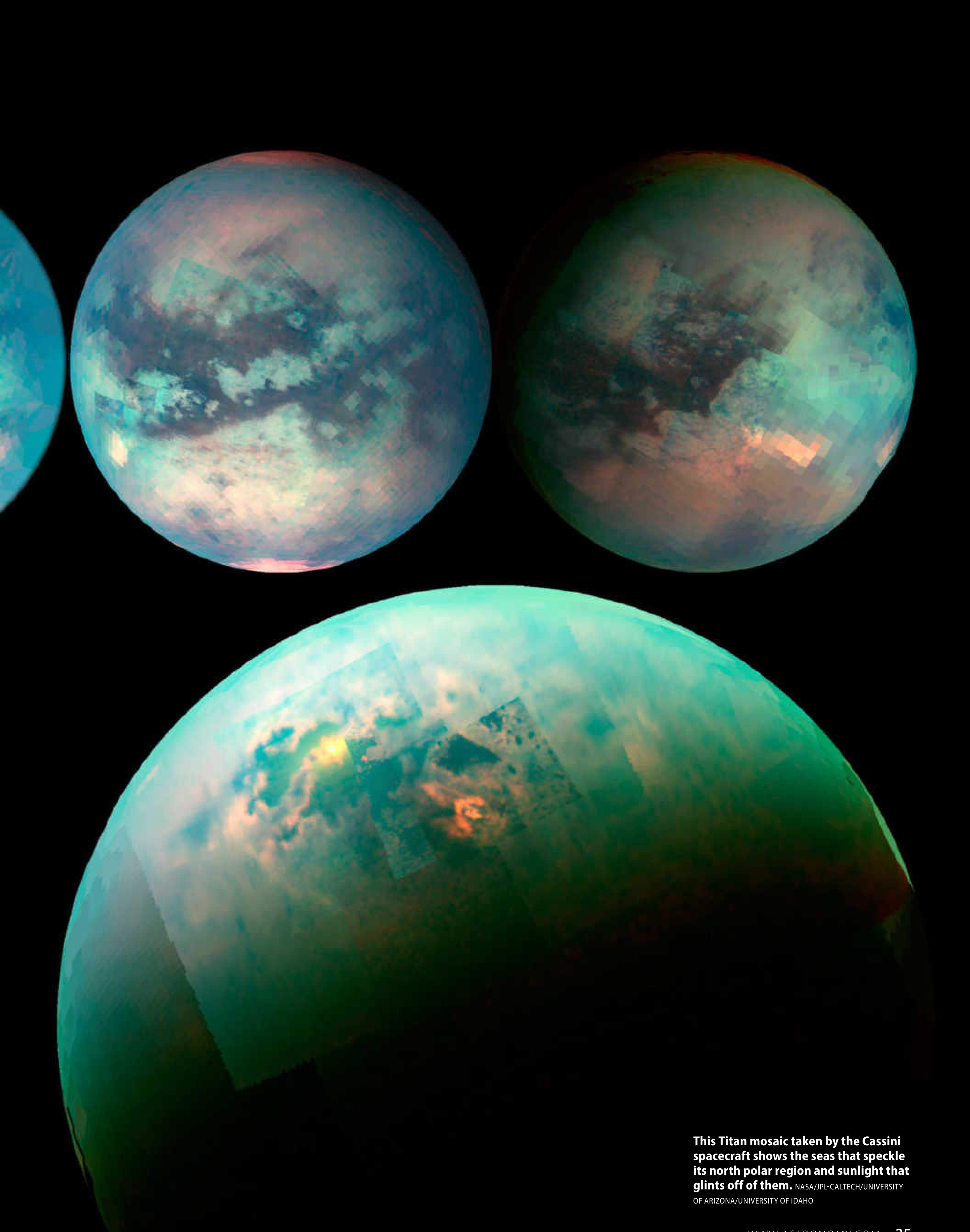
If you can picture all of this, welcome to the surface of Saturn's largest moon, Titan.

Titan is the only extraterrestrial body known to support standing bodies of liquid on its surface and the only moon with a dense atmosphere. It is also an explorer's utopia, supporting landscapes that are uncannily similar to those found on Earth while also presenting a seemingly endless supply of intriguing mysteries, with fresh questions following each new discovery. Two recent findings in particular have revolutionized our understanding of Titan's lakes and seas: their unexpected transparency to microwave radiation and the appearance of mysterious "magic islands," which our research team has been privileged to bring to light. But Titan's environment amazed well before these latest discoveries.

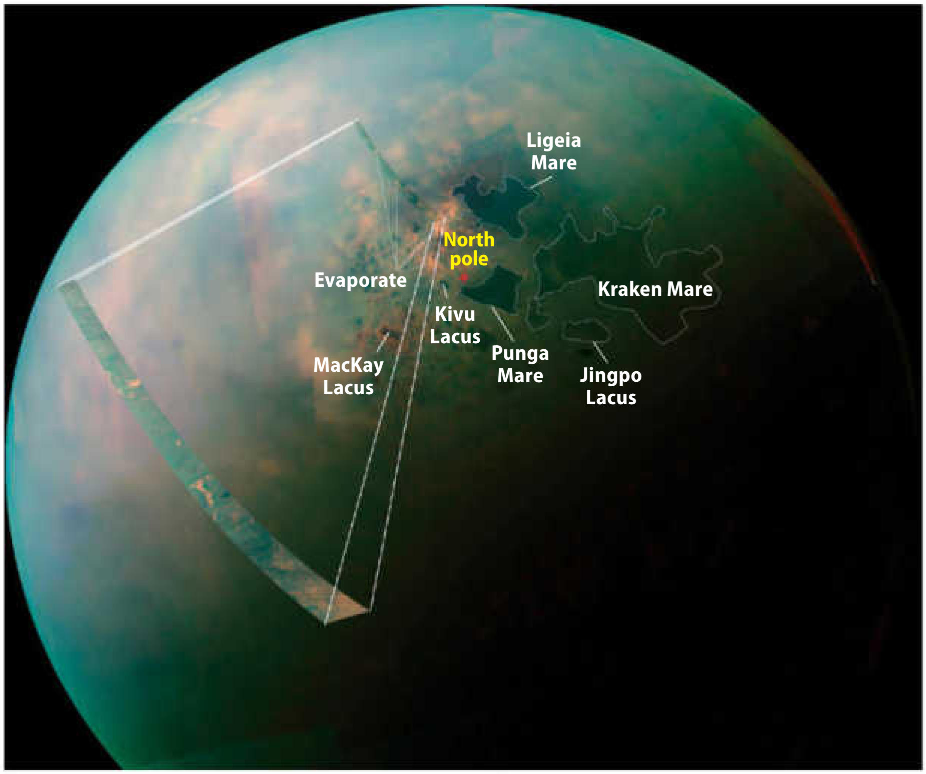
Alexander G. Hayes *is an assistant professor of astronomy at Cornell University. He and his research group focus on comparative planetology and solar system exploration, specializing in the development and operation of remote sensing instruments on unmanned planetary spacecraft.*

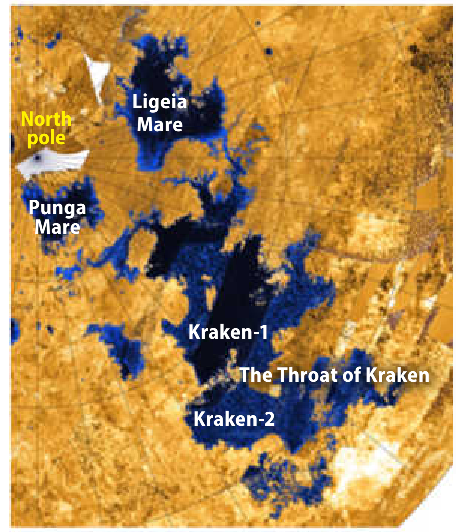
Strange but familiar

In many ways, Titan's landscapes are eerily similar to their terrestrial counterparts. You can find sand dunes similar in both



This Titan mosaic taken by the Cassini spacecraft shows the seas that speckle its north polar region and sunlight that glints off of them. NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA/UNIVERSITY OF IDAHO





▲ **Cassini's RADAR instrument took this detailed image of Titan's north pole and the many lakes and seas that cover its surface.** NASA/JPL-CALTECH/ASI/USGS

◄ **Many of Titan's intriguing details are visible in this Cassini infrared image. The surface appears largely in green, while dry lakebeds show up in orange. The lakes and seas that dot Titan's northern hemisphere are the darkest regions.** NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA/UNIVERSITY OF IDAHO

size and shape to the largest in the dune fields of the Saharan and Namibian sand seas of Africa. Alluvial fans (cone-shaped sediment flows left behind by rivers, streams, and landslides) resemble those found in the Atacama Desert of central Chile, and mountain chains are formed by tectonic forces similar to those responsible for the Himalayas that span southern Asia. Perhaps most astonishingly, lakes and seas scatter the polar landscape with shoreline features reminiscent of both marine and freshwater coastal environments found across our planet.

However, the dunes are not silicate sand; they are instead organic materials more like plastic than quartz. Rather than rock fragments delivered by flowing water, alluvial fans on Titan are a mixture of water ice and organic sediment delivered by flowing hydrocarbon liquids (methane and ethane). The mountains are broken-up sections of dirty water ice, and the lakes and seas are vast pools of liquid hydrocarbons. Despite these differences, the same mechanisms (such as wind and rain) sculpt and transport sediment across the landscape on Titan as they do on Earth. The similarities make Titan a natural laboratory for studying the processes that shape our own planet, including extreme conditions impossible to recreate in earthbound laboratories.

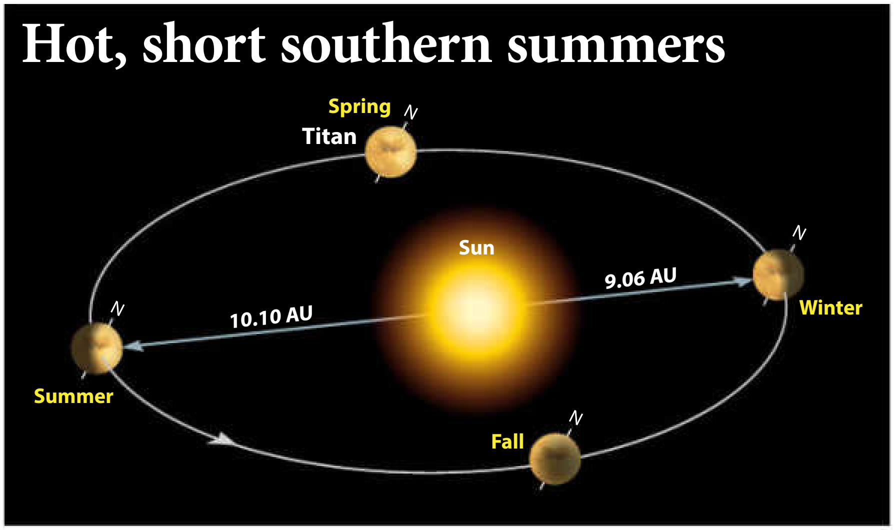
The forces that sculpt Titan's landscapes resemble Earth's water cycle, except that the key liquid is methane. Near the surface, methane makes up 5 percent of Titan's nitrogen-dominated atmosphere and, like water on Earth, condenses out of the atmosphere as rain and can persist as a liquid on the surface. If all of the methane in Titan's atmosphere were to fall down to the surface, it would make a global layer 23 feet (7 meters) deep. If you were to do the same thing to the water in Earth's atmosphere, the layer would be only 1 inch (3 centimeters) thick. On Titan, methane rain falls from the sky, flows on the surface, cuts channels into the bedrock, and fills depressions to form polar lakes and seas.

High in Titan's atmosphere, sunlight breaks apart methane in a process called photolysis (this also happens to methane in Earth's upper atmosphere). The methane splits into hydrogen, which escapes into space, and highly reactive compounds that quickly recombine to form more complex hydrocarbons like ethane and propane. These hydrocarbons rain out onto the surface and, over geologic time, rework themselves into the solid particles that make up Titan's dunes and coat the world's surface. Carl Sagan referred to laboratory-generated versions of the kinds of compounds Titan's atmosphere generates as "tholins" and noted that they are similar to the organic material that may have been important to the development of life on Earth. On Titan, these tholin-like materials form haze layers that obscure the surface from visible-light cameras, such as those on board the Pioneer 11 and Voyager 1 spacecraft.

Close encounters

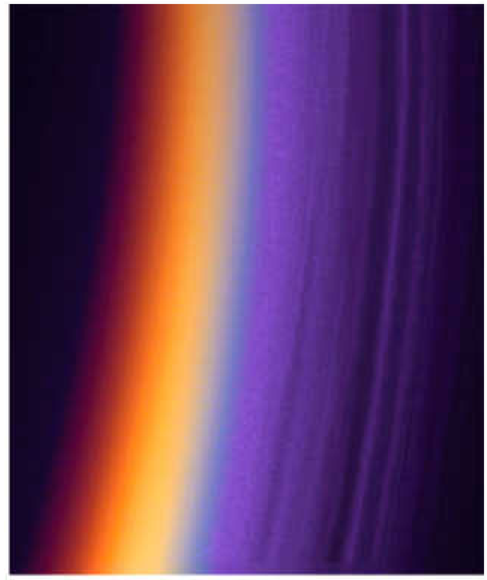
The presence of a thick atmosphere makes Titan unique among the moons in our solar system. It also made the saturnian moon one of the primary targets for exploration by Voyager 1. In fact, in order to reach Titan, Voyager 1 had to follow a specialized trajectory that eliminated the possibility of visiting Uranus or Neptune as Voyager 2 did on its "grand tour" of the solar system. While the cameras on Voyager 1 were not able to see down to Titan's surface, the spacecraft was able to use radio instruments to determine the surface pressure (1.5 times that of Earth) and temperature (92K). Following the Voyager encounter, scientists knew liquid methane and ethane were raining down and stable on Titan's surface but had no idea how they were distributed.

Prompted by the exciting results of the Voyager mission and the near two decades of ground-based imaging campaigns that followed, NASA and the European Space Agency (ESA) launched the Cassini/Huygens mission to Saturn in 1997. As a multipurpose mission, Cassini must divide its limited orbits around Saturn between many different moons (as well as the planet itself) and carefully allot its close flybys, but the spacecraft came specially prepared for Titan. In order to penetrate Titan's thick atmosphere,



ASTRONOMY: ROEN KELLY, AFTER NASA/JPL-CALTECH/UNIV. OF ARIZONA/CASSINI IMAGING & RADAR SCIENCE TEAMS

Seasons on both Earth and Titan are caused by each world's tilt, so that one side receives more direct sunlight. But on Titan, Saturn's eccentricity varies how far Titan orbits the Sun by more than an astronomical unit (AU; the average Earth-Sun distance), as well as speeding it up and down. This means the hemispheres don't share equal seasons, so the south has hotter, shorter summers than the north, driving liquid to the upper pole over eons.



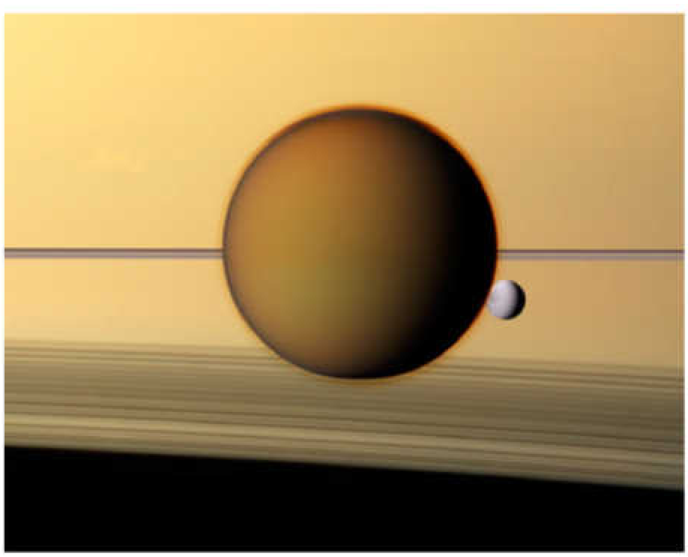
NASA/JPL/SPACE SCIENCE INSTITUTE

Titan's "purple haze" of an atmosphere is thanks to a thick shroud of methane, which separates into distinct layers upon closer inspection.

Cassini carries a radar mapper capable of obtaining images of the surface at a resolution of 1,000 feet (300m). The RADAR works by sending out bursts of microwave energy and measuring how much reflects back. Cassini contains two additional infrared instruments it uses to study Titan's surface, but their resolution is usually less than that of the RADAR. The Cassini orbiter also carried an ESA-provided probe, Huygens, which landed on Titan's surface in early 2005. Because at the time the surface of Titan was a mystery, engineers designed Huygens either to touch down on a solid surface or to land in an ethane sea. The probe touched down near Titan's equator on what appears to be a flood plain strewn with rounded cobblestones about 4 inches (10cm) in diameter.

Seasons and sunlight

The Saturn system tilts by 27° from the plane of its orbit, and thus Titan, like Earth, has seasons. Saturn and Titan, however, take 30 years to circle the Sun, so their seasons are 7.5 years long.



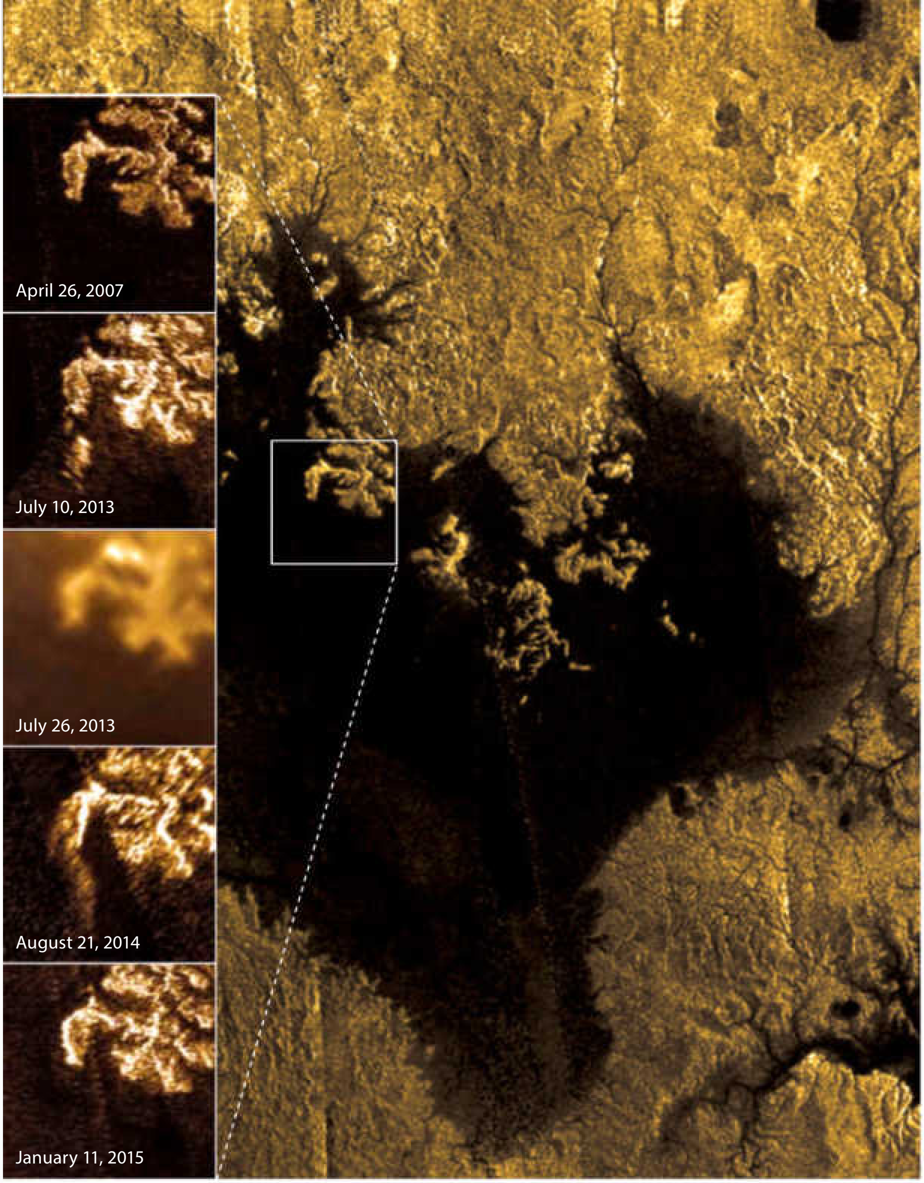
Titan poses here in front of Saturn's rings with its much smaller sibling moon Dione. The fuzzy outline of Titan is due to its thick, hazy atmosphere.
NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

The Cassini RADAR discovered Titan's lakes and seas in the north polar region during a flyby in July 2006, during northern winter. Since then, Cassini has discovered more than 300 liquid-filled depressions that range in size from moderately sized lakes at the limits of detection (about 90 acres, or 0.4 square km) to vast bodies larger than Earth's Great Lakes. The three largest, Kraken Mare, Ligeia Mare, and Punga Mare, hold the title "mare," which is Latin for sea. Collectively, the lakes and seas cover 1 percent of Titan's surface and lie mostly in the northern hemisphere, where they cover 35 times more area than in the south. We believe Saturn's eccentric orbit around the Sun causes this contrast between north and south.

Saturn is closest to the Sun during summer in Titan's southern hemisphere, when it tilts areas below the equator toward our star's most direct light. Northern summer, on the other hand, happens to occur when the Saturn system is farther from the Sun. As a result, southern summers are both hotter and shorter, with more intense sunlight than their northern counterparts. Over many seasons and years, the stronger, hotter sunlight in the south drives methane and ethane toward the northern hemisphere. But if this is the explanation for Titan's lake distribution, we should also note that it changes with time. The position of Titan's seasons on Saturn's eccentric orbit varies over periods of 50,000 years. In fact, 35,000 years ago, the situation was the exact opposite of today's scenario: Northern summers were hotter and shorter than southern summers. This suggests that the liquid in Titan's polar regions shifts between the poles over timescales of 50,000 to 100,000 years. And, in fact, there are large-scale depressions in the south that include features reminiscent of old shorelines along their borders. These paleo-seas encompass an area similar to the northern maria and suggest that Titan's south pole once looked similar to the north. This orbitally driven mechanism is analogous to the cycles on Earth that drive the frequency and duration of the ice ages.

Wind and waves

For most of Cassini's mission, its instruments observed Titan's lakes and seas to be calm and flat, with vertical deviations of



Titan's "magic islands" appear and disappear in Ligeia Mare from one observation to the next. They are more likely to be debris, waves, or bubbles than any supernatural occurrence. CORNELL UNIV./JPL-CALTECH

Titan's surface (left) can bear striking resemblance to Earth, where eons of flowing liquid — hydrocarbons or water — have shaped their surfaces and scattered debris across the landscapes. NASA/JPL/ESA/UNIVERSITY OF ARIZONA AND S.M. MATHESON

less than a few millimeters. This was surprising because the lower gravity and reduced surface tension and viscosity of liquid methane, as compared to water on Earth, should make it easier to excite wind waves.

Furthermore, we know that winds blow near Titan's equator because we see dunes. So why don't we see waves in polar lakes? After applying modern theories of wind-wave generation to Titan, scientists realized the absence of waves was most likely a seasonal effect resulting from light winds during the fall and winter. Researchers expected winds to freshen as Titan approached northern summer, with predicted speeds sufficient to sporadically ruffle the faces of hydrocarbon lakes and seas. Now, as predicted, Cassini has recently started to see indications of wave activity, such as sunlight glinting off ripples on the surface. Spurred by these results, research groups — my own included — began actively searching for activity in the lakes and seas, and the effort is delivering rich and often unexpected rewards.

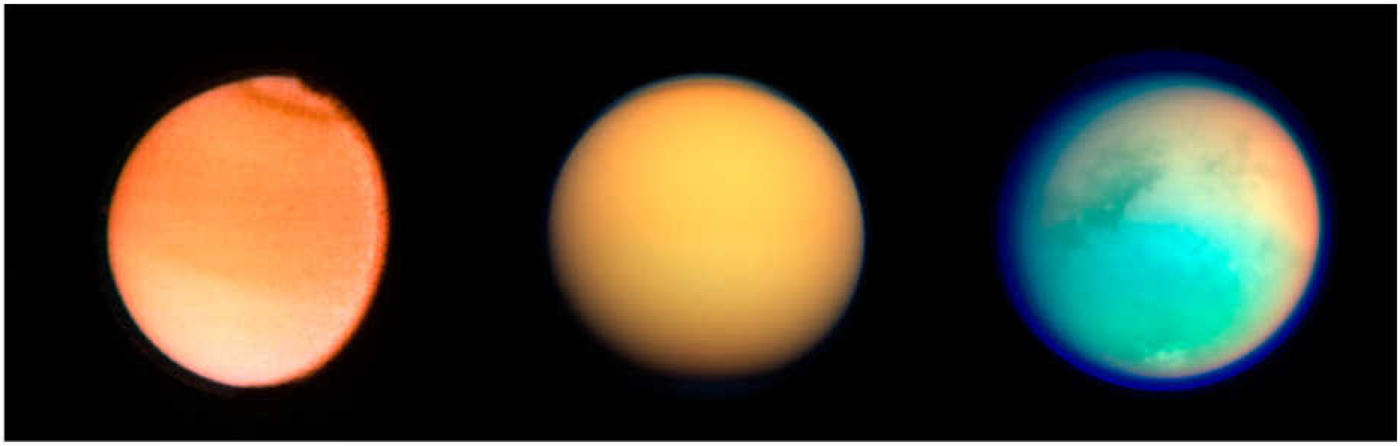
Old instrument, new tricks

In May 2013, the Cassini RADAR observed Ligeia Mare using its altimetry mode. In this mode, the instrument points straight down and measures the distance to Titan's surface by the round-trip travel time of the echo, similar to sonar. It also can read the roughness and composition of the surface through the intensity of the observed reflection. We intended this particular measurement to search for waves on the surface of Ligeia Mare.

While we didn't find any sign of waves, Cornell researcher Marco Mastrogiuseppe, an associate member of the Cassini RADAR team, re-examined the data and discovered two returns for each transmitted radio burst over the sea. The first return was from the surface of Ligeia, while the second was from the seafloor! The time delay between these two returns provided the first depth measurement of a Titan sea, showing that Ligeia Mare varied from 0 to 525 feet (160m) in depth along the observed range. This measurement is remarkable because it required the transmitted radio waves to pass through over 1,000 feet (300m) of liquid (to the floor and back again) without being completely absorbed. For comparison, the RADAR only would be able to penetrate 1 centimeter of seawater. The absorptivity of the liquid tells scientists what it is made of — primarily methane. This substance is four times less absorptive than ethane and 10,000 times less absorptive than seawater.

As a result of Mastrogiuseppe's discovery, the RADAR team redesigned two of Cassini's final three north polar flybys to obtain altimetry observations over the Kraken and Punga maria. These passes revealed the depth and composition of all three seas and proved that, contrary to expectations, methane, not ethane, is the dominant component. We have also applied Mastrogiuseppe's techniques to previous observations of the largest southern lake, Ontario Lacus, and showed it to be up to 300 feet (90m) deep and have 50 percent higher absorptivity then Ligeia. This increased absorption means the lake holds even more complex hydrocarbons, which may have slowly accumulated in Ontario with the transport of methane and ethane to the north over thousands of years.

These results have literally added a new dimension (liquid depth) to our understanding of Titan's lakes and seas and also showcase the adaptability and collaborative nature of the Cassini science team, who gave up long-standing observations of other key areas on Titan in order to accommodate these new altimetry



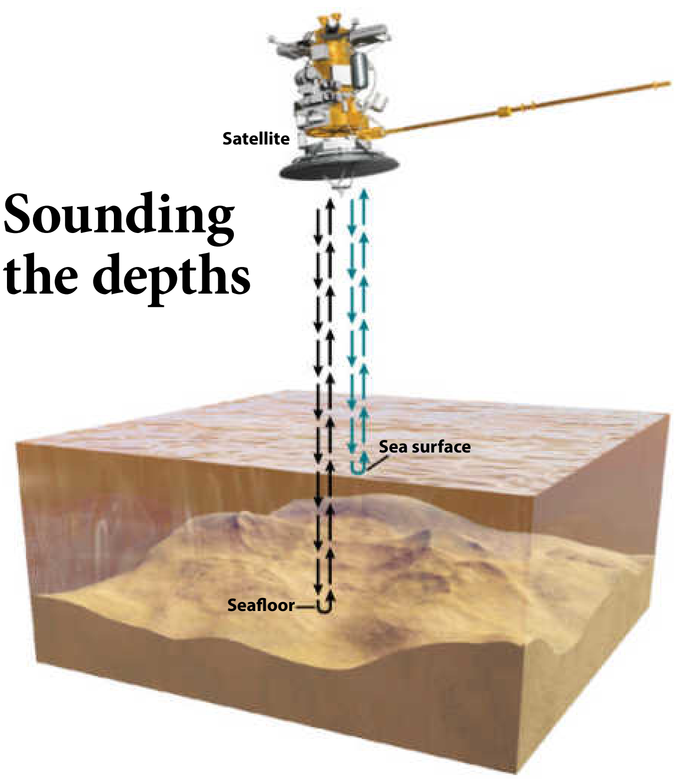
Views of Titan change dramatically from Voyager 2's flyby in 1981 (left) to Cassini, shown both in natural colors (center) and then peering through different cloud layers by using infrared and ultraviolet cameras. NASA/JPL (LEFT); NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE (CENTER, RIGHT)

observations. When considered collectively, the findings reveal that the surface liquid on Titan encompasses a volume of 17,000 cubic miles (70,000 cubic km), which is 15 times larger than the volume of Lake Michigan and equivalent to 300 times the mass of the entirety of the natural gas reserve on Earth.

"Magic islands"

Two months after the altimetry pass over Ligeia Mare, the RADAR re-observed the sea in imaging mode. Near a peninsula along the southeastern shoreline, it saw a 6-mile-long (10km) region of previously dark sea now to be nearly as bright as the surrounding shore.

Sounding the depths



Cassini's RADAR instrument operates in altimetry mode by bouncing radar signals off Titan's surface. By measuring the difference in timing between bounces off the sea's floor and surface, astronomers measured the changing depth of Titan's seas. *ASTRONOMY*: ROEN KELLY, AFTER SCRIPPS INSTITUTION OF OCEANOGRAPHY

At first, the RADAR team collectively dismissed the bright feature as merely a blip in the data. But it intrigued Jason Hofgartner, a Cornell University graduate student in our research group, who pursued the analysis. Hofgartner's work proved that the features were not a blip but represented real changes at Ligeia. Despite the significant resource reallocation required, the team modified several of the precious few remaining RADAR passes in order to reobserve the area and document its evolution.

During this campaign, transient features appeared and disappeared at both the Ligeia and Kraken maria. Researchers affectionately dubbed them Titan's "magic islands," and they highlight the moon's dynamic seasonality. While the origins of the islands remain unknown, the most likely hypotheses include waves, floating debris, or bubbles. Whatever their cause, without the tenacity and determination of a young scientist who was in elementary school when Cassini launched from Earth, we would have not discovered the magic islands at all.

Learning more

Just as Earth's history is tied to its oceans, Titan's origin and evolution are chronicled within the nature of its lakes and seas. Their discovery has shown us that oceanography is no longer just an Earth science. Despite vastly different environmental conditions, Titan is arguably the most Earth-like body yet discovered and presents a mirror — however distorted — through which we can learn about our own planet. While the Cassini/Huygens mission has provided a wealth of information on the location and depth of Titan's lakes and seas, it has only scratched the surface regarding their composition and interactions with the atmosphere. Addressing these fundamental questions requires visiting them close-up.

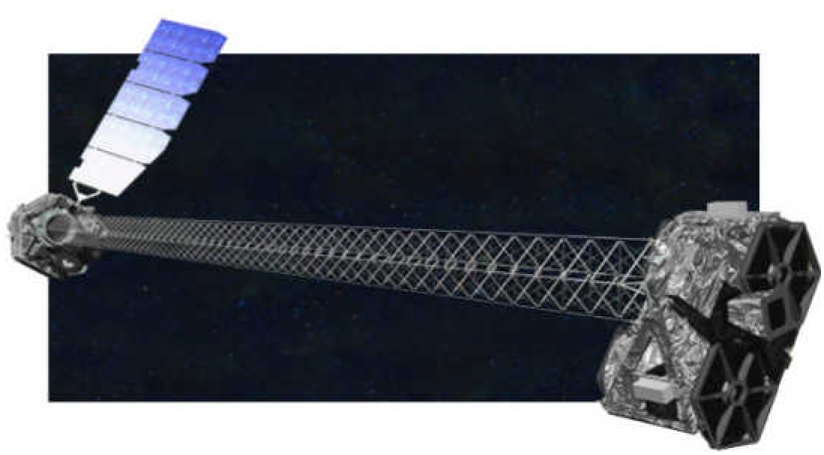
Various groups have proposed a wide range of concepts for future Titan missions, including exploration of its maria. While no missions are currently scheduled, NASA nearly selected a capsule called the Titan Mare Explorer (TiME) in 2010, and interest remains high. On-site exploration of Titan's lakes and seas would let us directly observe liquid-atmosphere interactions, read the history of the moon's evolution in its atmosphere and surface, and investigate a natural laboratory for the limits and requirements of life by examining trace organics in the seas. It is my enduring hope that, within our lifetimes, someone will write this article's sequel describing discoveries from the first extraterrestrial boat to explore a Titan sea.

LEARN MORE ABOUT HOW SATURN'S ORBIT CHANGES TITAN'S SEASONS AT **www.Astronomy.com/toc.**

High-energy astrophysics

What lurks in the MONSTROUS of the Milky Way?

NASA's bargain X-ray space telescope, NuSTAR, is revealing hidden secrets from the supermassive black hole at the center of our galaxy. **by Liz Kruesi**



Dust normally obscures the Milky Way's galactic center. This view stacks images from NASA's Great Observatories — Hubble, Chandra, and Spitzer — to pierce the veil by combining visible, X-ray, and infrared light. NASA/JPL-CALTECH/ESA/CXC/STScI; NASA/JPL-CALTECH (NUSTAR)

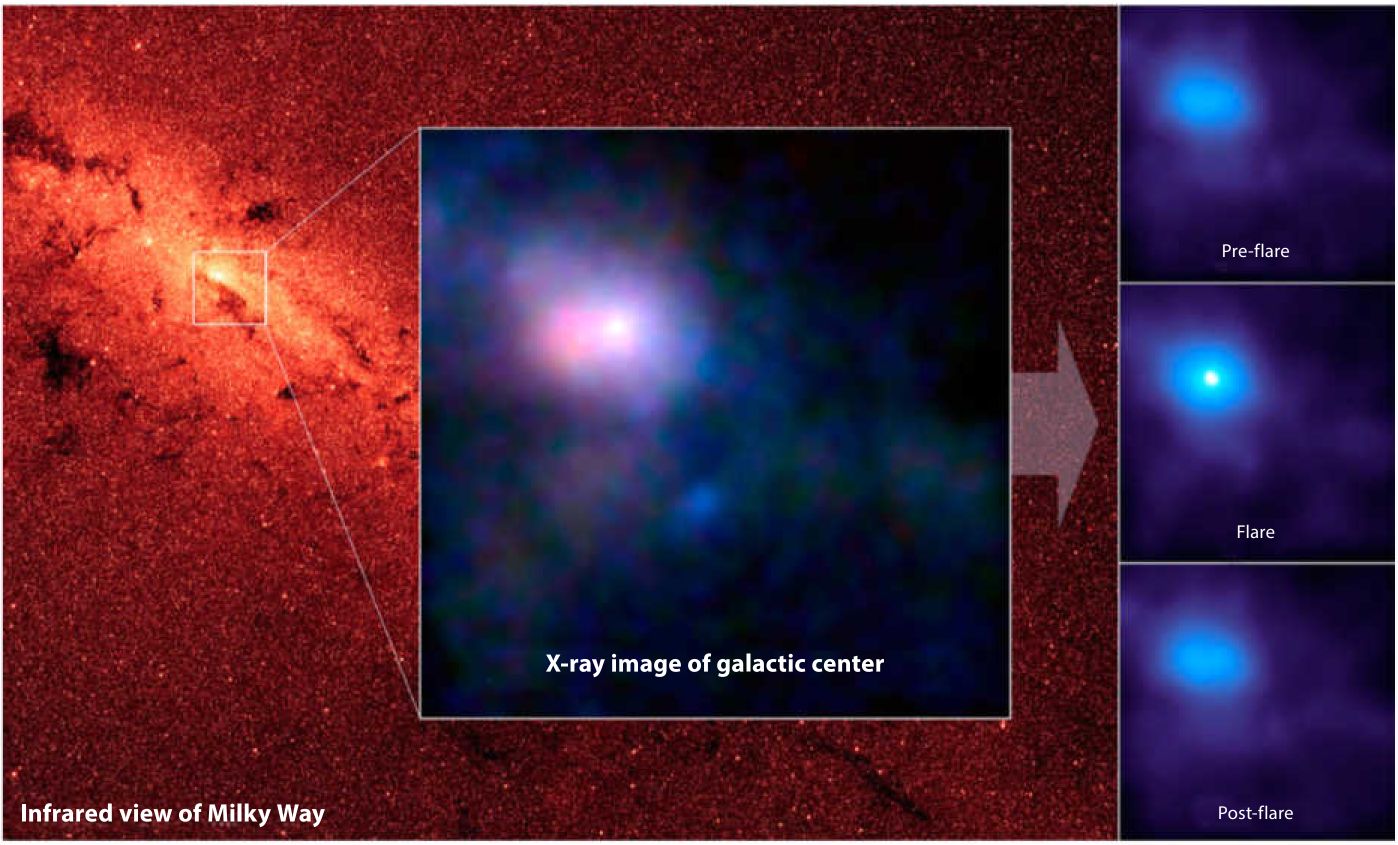
For 24 terrifying minutes, Fiona Harrison and her team watched the spikes in electric current. Each burst indicated that another one of their space telescope's tinker-toy-like sections had exited its holding cell and locked into place. With the 57 sections fully deployed, a school-bus-sized mast now separated the telescope's main optics from the cameras that would focus and collect the highest-energy X-rays for the first time.

Harrison is the principal investigator for the Nuclear Spectroscopic Telescope Array (NuSTAR) mission and a professor of physics and astronomy at the California Institute of Technology. She says she felt a combination of elation and nervousness while watching data from each step of the deployment. What she calls her "24 minutes of terror" — likened to the Mars Curiosity team's "seven minutes of terror" during the rover's landing sequence — followed nine days after NuSTAR launched June 13, 2012.

Before they sent the X-ray telescope into space on a rocket attached to the belly of Orbital Sciences' Stargazer aircraft, mission scientists had to test everything. The spacecraft was shaken and put through extreme temperatures. But no one can easily check how something will work in a gravity-free environment. So the NuSTAR team never tested the mast's delicate structure unfolding with all of its instruments. Instead, the first time the entire spacecraft was deployed was after they launched it into space.

The researchers weren't sure if it would operate properly when the time came. "But it did; it worked perfectly," Harrison says.

In the three years since that harrowing summer day, the observatory has given Harrison and her colleagues incredible views of



NuSTAR watched X-ray flares burst from the supermassive black hole at the Milky Way's center over the course of several days in 2012. The hottest material, which reached up to 180 million degrees F (100 million degrees C), is shown in white. NASA/JPL-CALTECH

the high-energy universe. Some of NuSTAR's most exciting discoveries have been at the very center of our Milky Way Galaxy. There, in an area a few hundred light-years wide surrounding a supermassive black hole, astronomers can explore some of the most extreme objects in the cosmos.

The black hole laboratory

The crown jewel of our galaxy is a black hole packing the mass of more than 4 million Suns. Like any black hole, this one, called Sagittarius A* (pronounced "A-star"), isn't directly visible. Instead, astronomers know it exists because they've tracked the orbits of nearby stars around it. And they've watched radiation outbursts as material circles the gravitational drain and is swallowed as a snack.

But Sagittarius A* and the stars used to discover its presence are not alone in the galactic center. This region — about ½° by ½° on the sky, or some 230 light-years on either side — contains thousands of objects. The dense cores of stars, filaments of hot magnetic gas, clouds of cold gas and dust, the scattered remains of dead massive stars — all are crammed around this supermassive black hole.

Astronomers look to the galactic center to study one of the most extreme environments in space. So it's no surprise that the region is one of NuSTAR's primary targets.

This telescope detects the most energetic form of X-rays, which astronomers call "hard" X-rays. Specifically, NuSTAR gathers photons thousands of times more energetic than those of visible light. Harrison's team accomplishes this thanks to the observatory's twin telescopes, each composed of 133 concentric reflective cylinders that capture and guide X-ray photons to an associated camera 33 feet (10 meters) away. Both cameras pack four cadmium-zinc-telluride detector chips, which convert high-energy photons of light into electronic signals.

But NuSTAR is actually a fairly simple observatory — scientists point toward a target and collect the light on those detectors. In that collected light, they get a photograph of the sky, the energy spectra (each color's intensity) for everything in the field of view, and specific timing information about when each photon fell on the detector. In a way, it's three instruments in one.

The ability to collect this much information for each observation has been crucial for NuSTAR scientists, especially when studying targets that change rapidly. Several of the observatory's major findings at the galactic center required this data haul.

Bright flares, long screams

Our galaxy's supermassive black hole lets out frequent blasts of energy. The Chandra X-ray Observatory spotted the first flares from Sagittarius A* in 1999. Since then, astronomers have seen the black hole outburst an average of twice a day in infrared and once per day in low-energy "soft" X-rays. But they still have no idea what's causing these flares.

Despite these extremes, the Milky Way's supermassive black hole is relatively weak in comparison to the active galaxies astronomers have turned up in recent years. But its proximity makes it an ideal place to learn about all galactic cores.

"This is by far the closest supermassive black hole, and we're still really scratching our heads to figure out why it is such an incredibly faint source," says Boston University's Joey Neilsen,

Contributing Editor **Liz Kruesi***'s coverage of black holes in* Astronomy *magazine won her the 2013 David N. Schramm award for high-energy astrophysics science journalism.*

who uses Chandra to study these flares. "These bright flashes of radiation have to be telling us something really interesting about the immediate neighborhood of the black hole."

The data they have so far match many different scenarios, from rocky objects being torn apart to magnetic field lines twisting and breaking. "In principle, if you combine [our] data with data from Chandra and other observatories, we should be able to figure out what the mechanism is by which these flares are being produced," says Columbia University's Chuck Hailey, who leads the NuSTAR galactic plane survey. But because the intensity of the energy from such an outburst drops steeply at higher energies, NuSTAR needs the brightest flares. "Something above 40 times the quiescent, or sleeping, state of the supermassive black hole is what we want" for a thorough analysis, Hailey adds.

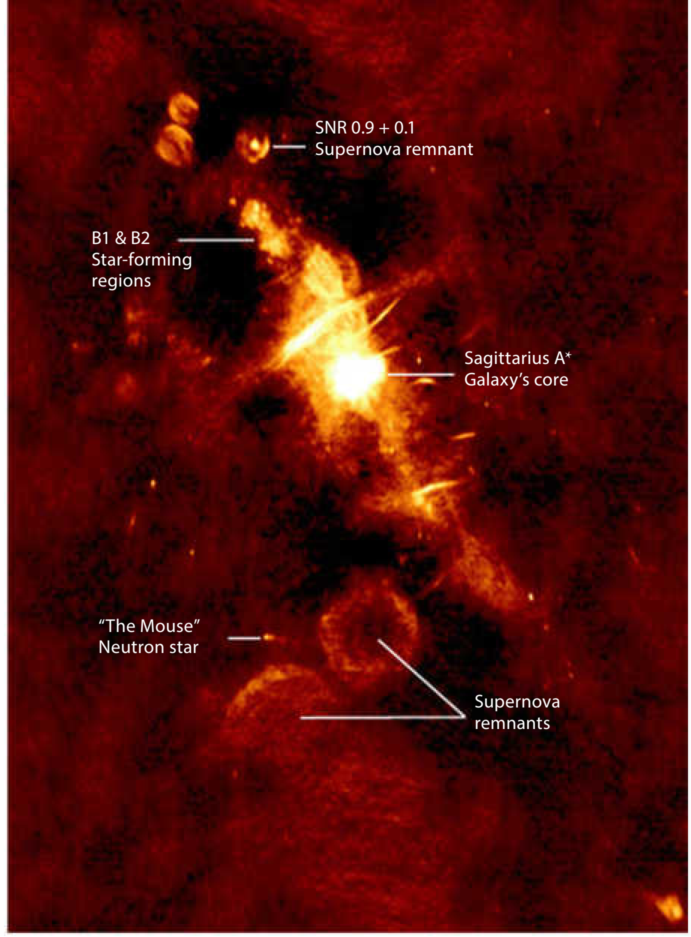
And astrophysicists were lucky, at least at first. In NuSTAR's first four months, the telescope spied two brilliant flares about 50 times brighter than the black hole's baseline and two fainter ones closer to about 20 times the intensity. But they've pointed the telescope at Sagittarius A* several more times and only seen faint flares.

One of the main complications with finding the flares is that there's another "annoying" source at the galactic center. In this region lie many binary systems, each containing a neutron star and a lower-mass companion Sun. As the companion dumps material onto the neutron star, that material heats up and emits X-rays. Astronomers have known since 2003 that one of these binaries sits just 3 light-years from Sagittarius A*. And in May 2013, this object decided to show off.

"It seems to be letting out a particularly long scream," says Hailey. Luckily, such an X-ray binary is intermittent, and it will quiet down again. When it does, NuSTAR researchers will look back at Sagittarius A* and await additional flares. Hailey is positive the telescope will capture them. "There's no doubt in my mind that over the next couple of years, we're going to see some bright flares."

Until then, scientists are looking for the echoes of Sagittarius A*'s past flaring. Large nearby gas and dust clumps, called molecular clouds, reflect X-rays from previous flares. That reflected light takes a longer path to get from Sagittarius A* to Earth, so astronomers see this light echo decades to centuries later. By studying data from Chandra and other X-ray telescopes, scientists recently realized that the black hole let out several larger flares or a gigantic one hundreds of years ago.

"It is possible that Sagittarius A*'s activity is unusually quiet now but it was more active in the past," says Columbia University's Kaya Mori, who is leading an analysis of the nearby molecular clouds. The NuSTAR team doesn't have any definitive results yet, although they plan to release a peer-reviewed paper soon.



The Milky Way's center, invisible to our eyes, is home to some of the most exotic objects in the universe. NRAO/AUI AND N.E. KASSIM, NAVAL RESEARCH LABORATORY

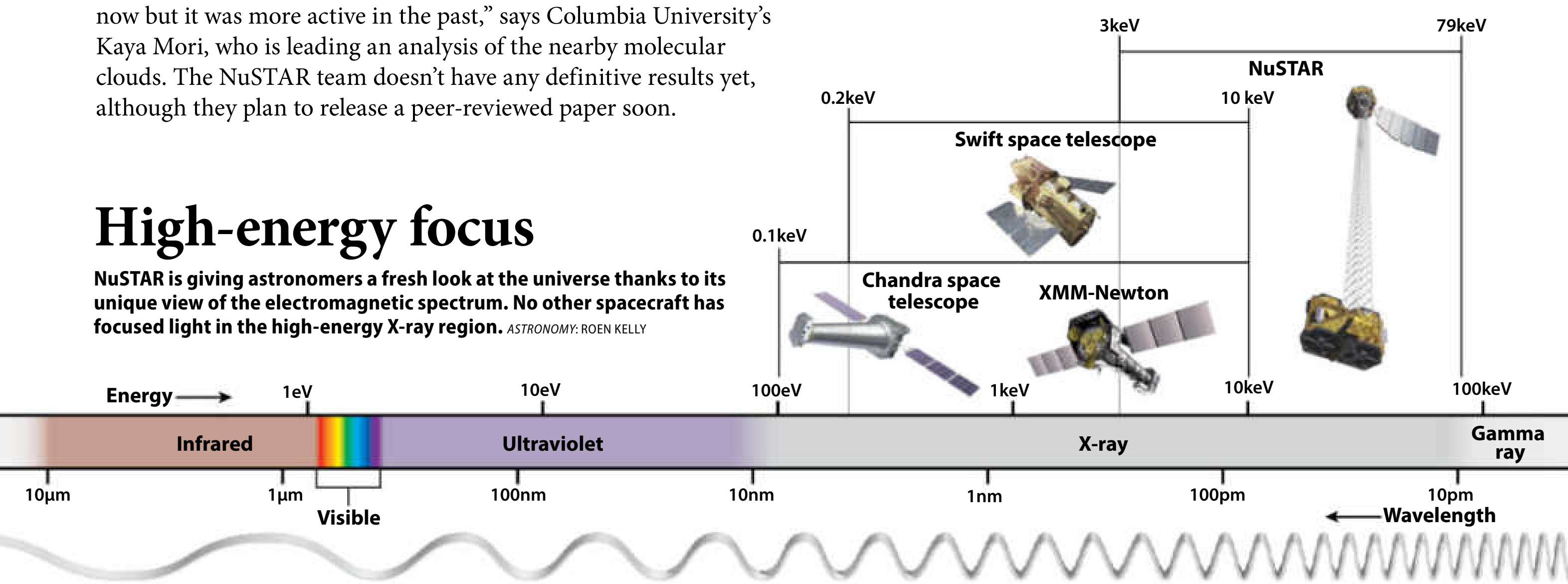
Found: magnetic monster

These screams aren't the only excitement NuSTAR has seen at the galactic center. On April 24, 2013, another NASA telescope, Swift, which scours the sky for bursts of hard X-rays and gamma rays, detected a brilliant X-ray flare at the same site.

High-energy astrophysicists hoped this signal indicated the dusty gas cloud called G2 had begun interacting with the supermassive black hole. This object, discovered in late 2011, has had a case of conflicting personalities. Some scientists believe it's a gas cloud harboring a star while others think it's just a cloud.

High-energy focus

NuSTAR is giving astronomers a fresh look at the universe thanks to its unique view of the electromagnetic spectrum. No other spacecraft has focused light in the high-energy X-ray region. *ASTRONOMY:* ROEN KELLY



Principal Investigator Fiona Harrison of the California Institute of Technology was awarded this year's Rossi Prize, the highest award in high-energy astrophysics, for assembling and leading the NuSTAR team, which has "opened a new window on the universe." LANCE HAYASHIDA/CALTECH MARCOMM

NuSTAR was launched from a Pegasus rocket strapped to the belly of Orbital Science's Stargazer aircraft in 2012. ORBITAL SCIENCES CORPORATION

Whatever G2 is, it swung nearest the black hole in early 2014. As it came about 240 times the Earth-Sun distance from Sagittarius A* and rammed through the black hole's dense environment, astronomers expected G2 would feel a shock and light up before being torn apart by the black hole's gravity. So they kept turning their X-ray, radio, and infrared telescopes toward the galactic center to see the first sign of this interaction. When Swift caught the brightest flare it had ever detected at the galactic center, astronomers were ecstatic they were about to watch the G2 show.

Two days later, NuSTAR came on the job. The hard X-ray scope detected bursts of X-rays spaced 3.76 seconds apart — a strong sign that the blast Swift saw was not a result of the G2 interaction but instead from an extremely magnetized type of neutron star called a magnetar. These neutron stars spin relatively slowly, completing each rotation in about two to 12 seconds.

The clincher piece of evidence came when Mori's team measured a small change in the pulsation period, called the spin-down rate. "The spin-down rate, combined with the period, gives you an estimate of the magnetic field strength of the neutron star," explains Victoria Kaspi, a neutron star expert at McGill University in Montreal. "And that's what seals it."

Magnetars are the most magnetic objects in the universe. They have magnetic fields hundreds to thousands of times stronger than normal neutron stars, which are already a trillion times that of Earth. These extreme magnetic fields are unstable and can initiate cracks and shifting of the magnetar's surface, which releases a big burst of energy. Each time that cracked spot on the surface spins into view, telescopes detect the energy.

So far, astronomers have found 28 of these magnetic monsters, typically right after a major outburst.

Armed with the 3.76-second spin period discovered by NuSTAR, radio astronomers looked toward the galactic center and also detected the magnetar, called SGR J1745–2900. This observation came as a huge surprise because scientists had looked for radio-pulsing neutron stars in orbit around Sagittarius A* for years, says Kaspi. Such an object would be the ultimate tool to test the general theory of relativity and measure the black hole's mass precisely. "But people were doubtful you could ever do it because the intervening material, particularly in the galactic center region, is so great that those radio waves would be totally scattered away," she says.

The radio pulses from the magnetar imply there was much less scattering than models predicted. "It shows us there's potentially a much clearer window to the galactic center in radio waves," Kaspi adds. "And it reopens the hope that we can detect radio pulsars there and maybe one day do these amazing dynamical relativistic tests."

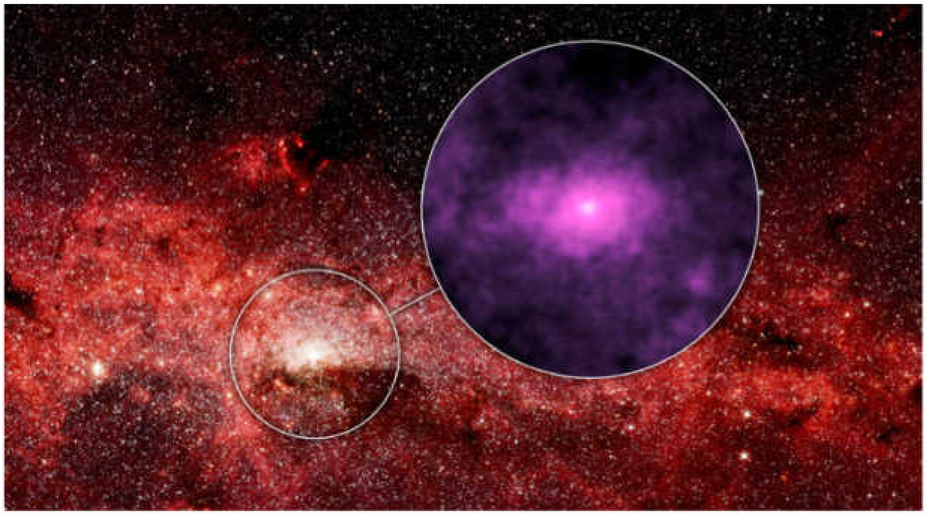
A stellar graveyard?

One of the best gifts a new telescope can give astronomers is an unexpected discovery. And that's precisely what NuSTAR has done.

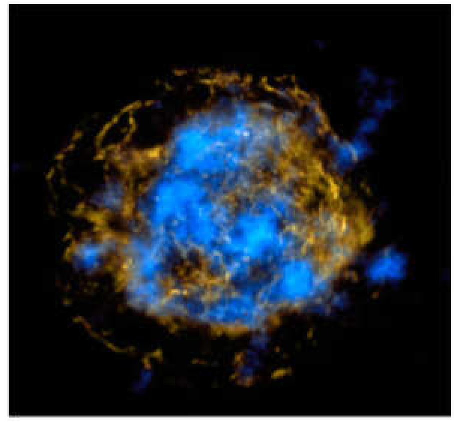
Most of the X-ray-emitting objects in the galactic center throw out only soft X-rays. For example, Chandra and Europe's XMM-Newton had detected a haze of soft X-rays in the Milky Way's central region. The light from this soft X-ray haze fades out at higher energies. While astronomers aren't positive yet what this haze is, the most likely source is the combined blaze of thousands of white dwarfs — the still glowing cores of once Sun-like stars that are stealing material from companion stars. Each of these white dwarfs holds about half the Sun's mass in an Earth-sized sphere.

While a postdoctoral fellow at Columbia University, Kerstin Perez was studying one of the rare galactic center objects that doesn't disappear at higher-energy X-rays. To concentrate only on this nebula, called G359.95–0.04, she had to subtract out the other signals from NuSTAR's data. But the object still appeared far too bright in these hard X-rays, says Perez, who's now at Haverford College in Pennsylvania.

She and her colleagues checked everything else the signal could be — stray radiation in the background, smeared light from the nebula, and even the Chandra and XMM soft X-ray haze that,



It might not look like much, but this magenta dot holds the Milky Way's heart of darkness — a supermassive black hole. NuSTAR's high-energy X-ray view of the galactic center is among the most detailed ever and shows a spinning dead star, or pulsar, as well as an unexpected X-ray haze. NASA/JPL-CALTECH



NuSTAR imaged the radioactive guts of a supernova remnant — Cassiopeia A — for the first time ever, shedding light on how stars die. Here, NuSTAR data of radioactive material (titanium) is blue and low-energy X-rays from the Chandra spacecraft are yellow.
NASA/JPL-CALTECH/CXC/SAO

maybe, doesn't fade out as expected. But the signal was still there. They discovered a bright haze in the central 13 by 26 light-years around Sagittarius A*, but "it's probably not really truly diffuse in the sense of being gas," says Harrison.

The astrophysicists have four potential sources for this new-found emission, but none is a perfect fit. "[All four] go against the common knowledge of how those objects work," says Perez.

Three of the four theories include compact objects in binary systems stripping material from their neighbors, like the pesky object that's frustrating X-ray scientists looking for Sagittarius A* flares. As this material piles up, it ignites and glows in X-rays. There could be so many of these binary systems that NuSTAR can't resolve them individually and thus sees them as a fog.

One of these exciting possibilities is an abundance of neutron stars and stellar-mass black holes. Swift, however, has been staring at the galactic center nearly every day for the past 9.5 years, and it's seen only a few such systems near Sagittarius A*. "We're saying we would need to hide a thousand of them," says Perez.

The fourth possible source of this hard X-ray emission is high-energy material flowing from the region very near Sagittarius A*. This might be bright flares from the black hole, and that light is interacting with nearby dense molecular cloud material. The problem with this suggested source is that the geometry of the clouds doesn't quite match the location of the emission that NuSTAR sees.

Out of all the theories, Perez finds the many black holes option the most exciting. But such a situation also would point to perhaps the most interesting questions. For a star to form a black hole at its death, it needs to start out extremely massive — at least 30 times our Sun's mass. How would so many massive stars get to the very center of the galaxy? And why hasn't any other X-ray telescope seen more than a few black hole binaries in the region?

In the meantime, scientists are using NuSTAR data to tally the point sources — like individual stars — that lie just about ¼° degree (about 115 light-years) north of the galactic center. They also will compare the spectral properties of those resolved sources to the emission.

"It's kind of like nibbling around at the edge of the emission to see if we can resolve it out into objects that have the same properties as what we see right at the center of the galaxy," says Hailey.

These major observations only scratch the surface of what NuSTAR has seen in the 1 million seconds it has so far stared at the X-ray glow of the galactic center.

The observatory has now entered its extended mission that will run until at least the end of 2016. Hailey says NuSTAR will spend roughly the same amount of time aimed toward the galactic center as it did in its primary mission.

After all, this is a fabulous location to study. "The galactic center is a fun place to look in high-energy X-rays just because almost anything that can emit in high-energy X-rays is there," Perez says. A region crammed with exciting celestial objects, all within a few fields of view of today's best instruments — it's the perfect astrophysical laboratory.

MAPPING A STAR'S SCATTERED REMAINS

NuSTAR's primary mission — which ran from August 2012 until fall 2014 — addressed four main science goals. While one was to study black holes like the one at the center of the Milky Way, another was to understand how a massive star explodes as a supernova at the end of its life. Astronomers try to simulate these stellar explosions on supercomputers, but they've long had a problem: Their stars don't explode. They had assumed supernova blasts were symmetric. But perhaps they're not.

To find out if such explosions are in fact symmetric, NuSTAR scientists looked for the distribution of an element produced in the high temperatures and pressures of supernova blasts: titanium-44 (Ti-44). This element is radioactive, meaning it releases electron antiparticles along with energy in the form of light photons as it decays to a different element. Those photons have specific energies, or colors; two of them are in NuSTAR's detection range.

NuSTAR stared at the young supernova remnant Cassiopeia A for about 1.2 million seconds in 2012 and 2013. When Brian Grefenstette of the California Institute of Technology and his colleagues analyzed the locations of Ti-44, they saw the material was spread asymmetrically throughout the blast's remnant. — *L. K.*

WATCH A VIDEO OF HOW NuSTAR UNFOLDED IN SPACE AT **www.Astronomy.com/toc.**

MARTIN RATCLIFFE and **ALISTER LING** describe the solar system's changing landscape as it appears in Earth's sky.

Visible to the naked eye
Visible with binoculars
Visible with a telescope

October 2015: Morning planet spectacle

On the evening of June 17, 1991, Venus gleamed above Jupiter while fainter Mars shone to their left. The same three planets converge in October's morning sky. ALAN DYER

Venus climbs higher before dawn than at any other time this decade, providing a dramatic focal point for the four bright planets visible in October's morning sky. Jupiter, Mars, and Mercury round out the remarkable quartet that awaits early risers.

The predawn scene holds only half of what skygazers can look forward to this month, however. The outer solar system puts its own stamp on the evening and overnight hours. Beautiful Saturn leads the way, ruling the southwestern sky as darkness falls. Once twilight fades away, Neptune and Pluto take center stage. Uranus represents the final piece of October's planetary puzzle. This distant ice giant reaches opposition and peak visibility in October, so it remains visible all night.

Our solar system tour begins with **Saturn**, which stands in the southwest as evening twilight falls. It forms a nice pair with ruddy Antares, located 10° southeast (left) of the planet. At magnitude 0.6, Saturn's yellowish orb shines half a magnitude brighter than Scorpius' lead star.

Venus, Mars, and Jupiter create dramatic scenes throughout October. On the 28th, the three form a tight triangle. ALL ILLUSTRATIONS: *ASTRONOMY*: KELLIE JAEGER

Look more carefully, and you'll notice a closer and fainter companion: 2nd-magnitude double star Beta (β) Scorpii. As Saturn moves eastward relative to the background stars, the gap between it and Beta narrows. The planet passes 0.7° due north of Beta on October 24.

A waxing crescent Moon passes through the scene in mid-October. On the 15th, it lies 8° to Saturn's right. The following evening, our satellite appears 6° to the planet's upper left.

If you want to catch a view of Saturn through a telescope, do so early in the month. On October 1, the ringed planet stands about 15° high an hour after sunset. By month's end, the gas giant has dropped to 5° altitude at the equivalent time and may be hidden by trees or buildings.

Still, Saturn rarely fails to impress even when it hangs low. In early October, the planet's disk measures 16" across while the rings span 36" and tilt 25° to our line of sight. Any telescope also shows 8th-magnitude Titan, Saturn's biggest moon.

As soon as darkness settles in, target the planet to Saturn's east: the icy dwarf **Pluto**. This distant world lies in northern Sagittarius, an area that stands 25° high in the south-southwest as twilight ends. With images pouring back from NASA's New Horizons spacecraft, providing humanity with its first close-up look at this surprisingly active planet, there's no better time to get your own view. You'll need an 8-inch or larger telescope and a clear moonless

Martin Ratcliffe *provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

RISINGMOON

Snaking across the Sea of Serenity

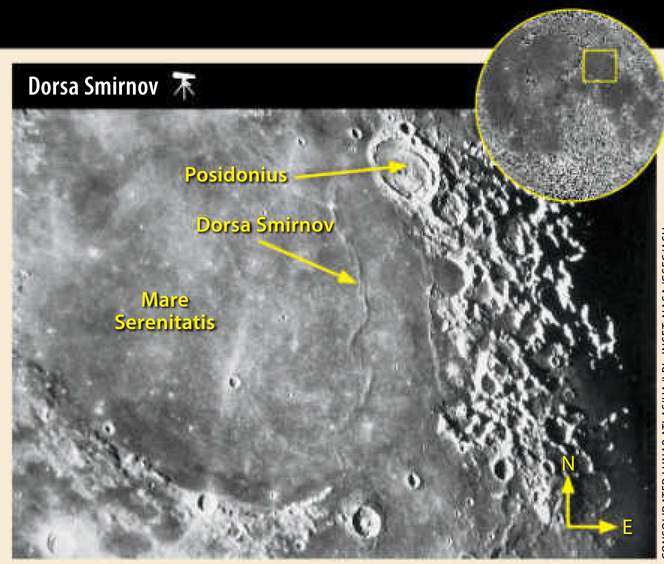
When the timing is right, the wrinkle ridge Dorsa Smirnov provides one of the more striking sights on the floor of Mare Serenitatis (the Sea of Serenity). Thanks to the way the lunar cycle fits our calendar, this happens three times in October 2015. When the Sun lies low in the lunar sky, Dorsa Smirnov's modestly lifted terrain casts shadows across the mare's hardened lava plains. The prominently paired dark and sunlit faces disappear under a higher Sun.

Because most amateur astronomers observe during evening hours, we normally focus on features visible just after lunar sunrise as the Moon waxes from crescent to Full. Yet during autumn evenings in the Northern Hemisphere, the Harvest Moon effect allows observers to view a waning gibbous Moon before midnight. On October 1, 2, and 31, the Sun begins to set over the Sea of Serenity in what some call "reverse lighting."

Dorsa Smirnov, also called the Serpentine Ridge, extends nearly 150 miles. This complex of ridges formed billions of years ago as the weight of newly erupted lava caused the Serenity basin to sag. As the lava slid inward, compression caused the surface to buckle gently upward.

Classic lighting on Dorsa Smirnov occurs October 18 during the Moon's evening crescent phase. Viewers in the western half of North America can catch the first rays of sunlight striking the top of the ridge on the 17th.

While you're in the area, also take a few minutes to explore the wonderful crater Posidonius just to the northeast. It's a joy getting lost in the magnificent detail of this 59-mile-wide impact feature. For starters, there are small craters, bumps, rilles, and a partial second wall.



The Serpentine Ridge, known officially as Dorsa Smirnov, winds across the eastern section of Mare Serenitatis.

sky or a telescope-camera combination that can reach to magnitude 14.2 Pluto.

You can find Pluto's general location easily. It lies 5° due north of magnitude 2.1 Sigma (σ) Sagittarii in the handle of the Teapot asterism and within shouting distance of magnitude 3.5 Xi^2 (ξ^2) Sgr. During October, Pluto moves from a position 0.7° west of Xi^2 to a spot just 0.4° west of this star. To confirm a sighting, sketch or image the field and return to it a night or two later. The object that changes location is the planet.

Pluto's closest neighbor among large solar system objects is **Neptune**, and this ice giant world happens to be the next planet to rotate into prime position. Neptune lies among the background stars of central Aquarius. In early October, it appears well above the southeastern horizon after

— *Continued on page 42*

METEORWATCH

The Hunter's four-hour reign of glory

Earth sweeps up debris cast off by Comet 1P/Halley twice every year. When our planet's atmosphere incinerates these tiny dust particles in May, we get the Eta Aquariid meteor shower; when the process repeats in October, the Orionid shower reigns supreme.

The Orionids peak this year the night of October 21/22. The waxing gibbous Moon sets around 1:30 A.M. local daylight time, leaving four hours of dark skies for observers. The meteors appear to radiate from Orion the Hunter's raised club, a region that climbs high in the south just before dawn. In its best years, the Orionids produce up to 70 meteors per hour, but astronomers predict 2015 rates closer to 15 per hour.

Orionid meteors

Active dates: Oct. 2–Nov. 7
Peak: October 21/22
Moon at peak: Waxing gibbous
Maximum rate at peak: 15 meteors/hour

The Moon sets by 1:30 A.M. local daylight time October 22, leaving several hours for nice views of October's pre-eminent meteor show.

OBSERVING HIGHLIGHT Uranus reaches its 2015 peak October 11/12, when it glows at magnitude 5.7 and appears 3.7" across through a telescope.

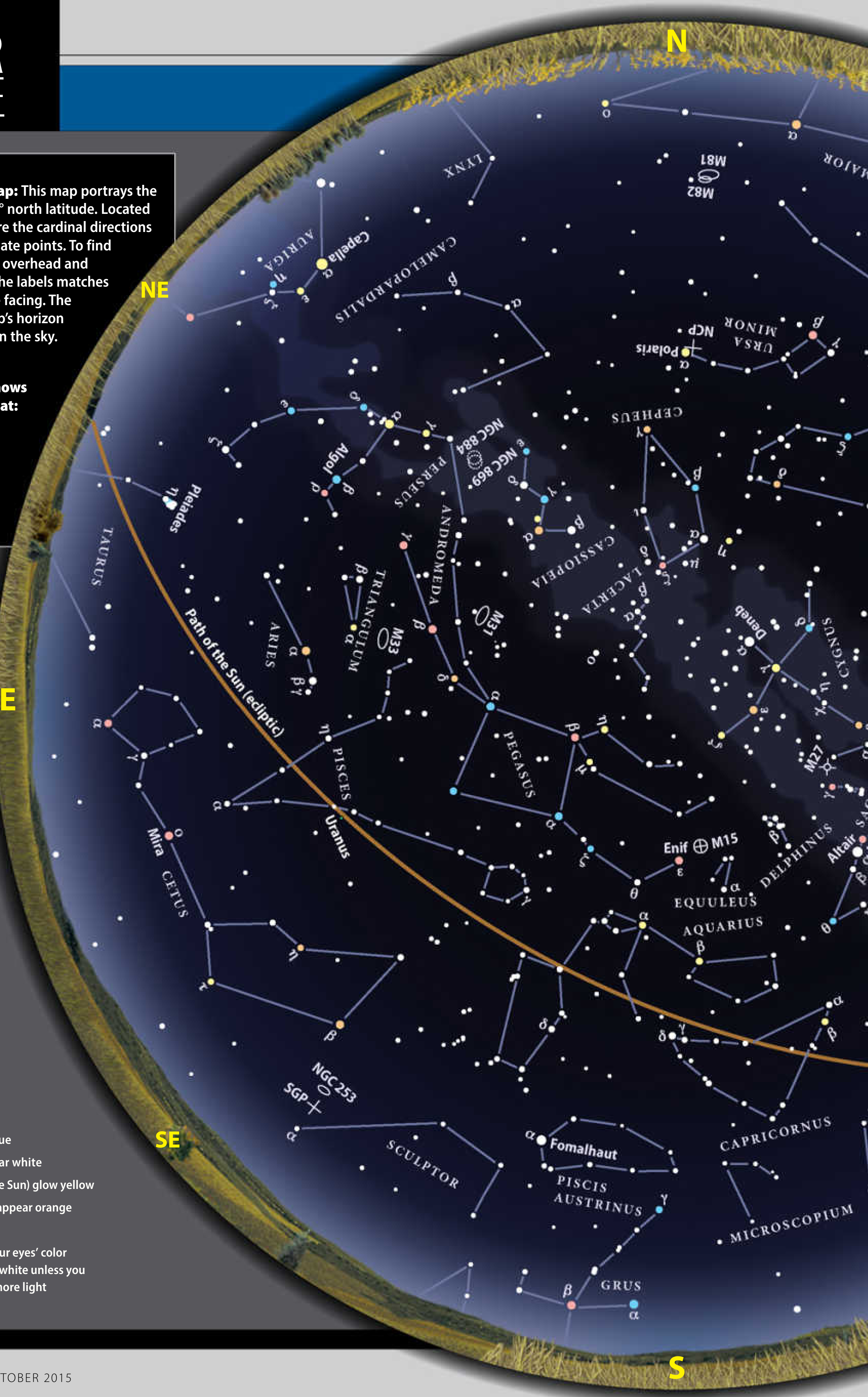
STAR DOME

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. October 1
9 P.M. October 15
8 P.M. October 31

Planets are shown at midmonth



STAR MAGNITUDES

Sirius
0.0
1.0
2.0
3.0
4.0
5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

OCTOBER 2015

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Calendar of events

2 The Moon passes 0.5° north of Aldebaran, 9 A.M. EDT

3 Asteroid Eunomia is at opposition, 7 A.M. EDT

4 Last Quarter Moon occurs at 5:06 P.M. EDT

8 The Moon passes 0.7° south of Venus, 5 P.M. EDT

Mercury is stationary, 6 P.M. EDT

9 The Moon passes 3° south of Mars, 1 P.M. EDT

Venus passes 3° south of Regulus, 5 P.M. EDT

The Moon passes 3° south of Jupiter, 8 P.M. EDT

11 The Moon passes 0.9° south of Mercury, 8 A.M. EDT

The Moon is at apogee (252,518 miles from Earth), 9:18 A.M. EDT

Uranus is at opposition, midnight EDT

12 New Moon occurs at 8:06 P.M. EDT

13 Asteroid Papagena is at opposition, 3 A.M. EDT

15 Mercury is at greatest western elongation (18°), 11 P.M. EDT

16 The Moon passes 3° north of Saturn, 9 A.M. EDT

17 Mars passes 0.4° north of Jupiter, 10 A.M. EDT

20 First Quarter Moon occurs at 4:31 P.M. EDT

21 Orionid meteor shower peaks

23 The Moon passes 3° north of Neptune, 3 P.M. EDT

25 Asteroid Amphitrite is at opposition, 8 A.M. EDT

SPECIAL OBSERVING DATE

26 Venus passes 1.1° south of Jupiter at 4 A.M. EDT, just one hour after Venus reaches greatest western elongation.

26 The Moon passes 0.9° south of Uranus, 6 A.M. EDT

The Moon is at perigee (222,739 miles from Earth), 9:01 A.M. EDT

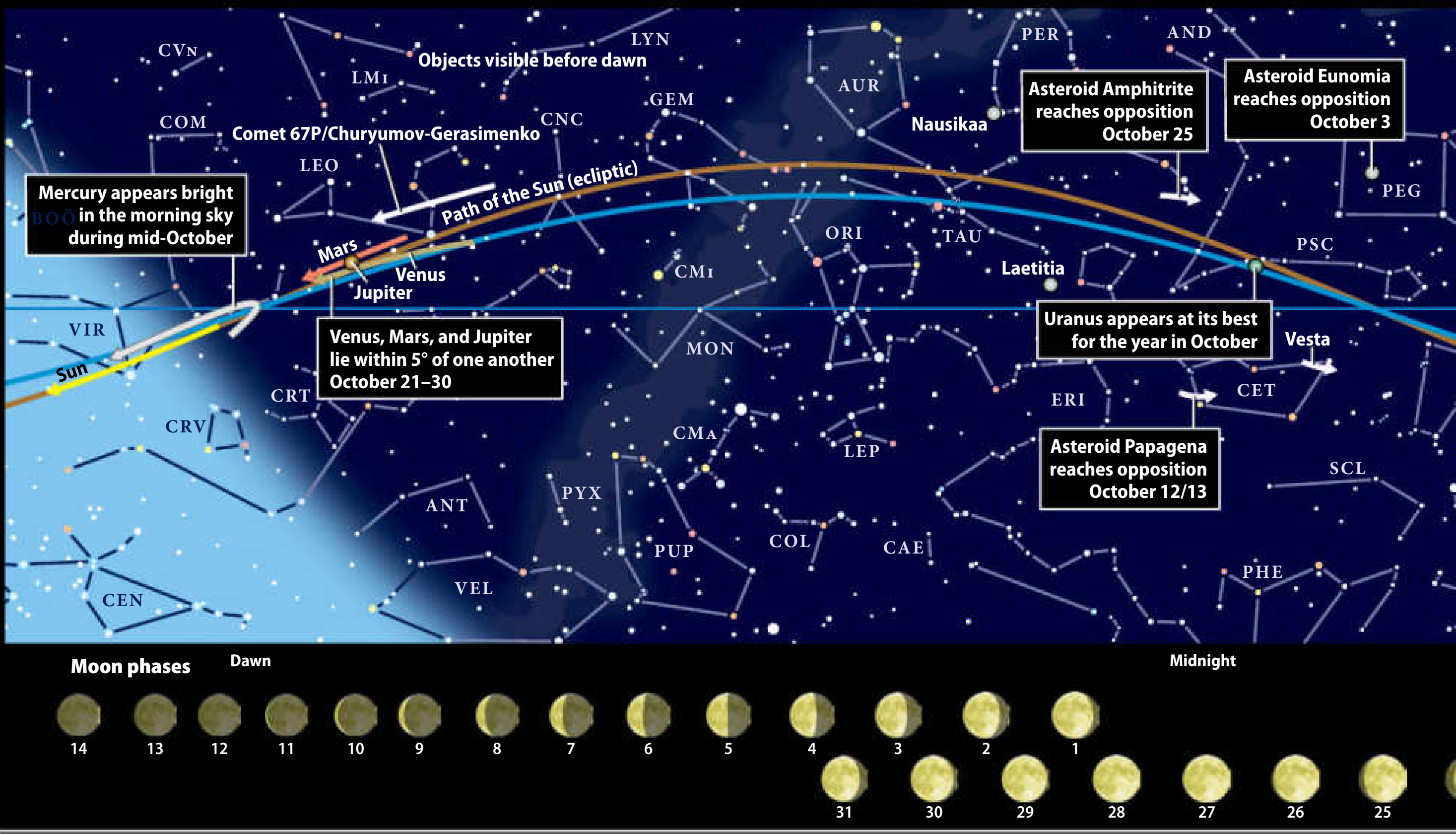
27 Full Moon occurs at 8:05 A.M. EDT

28 Mercury passes 4° north of Spica, 3 P.M. EDT

29 The Moon passes 0.6° north of Aldebaran, 7 P.M. EDT

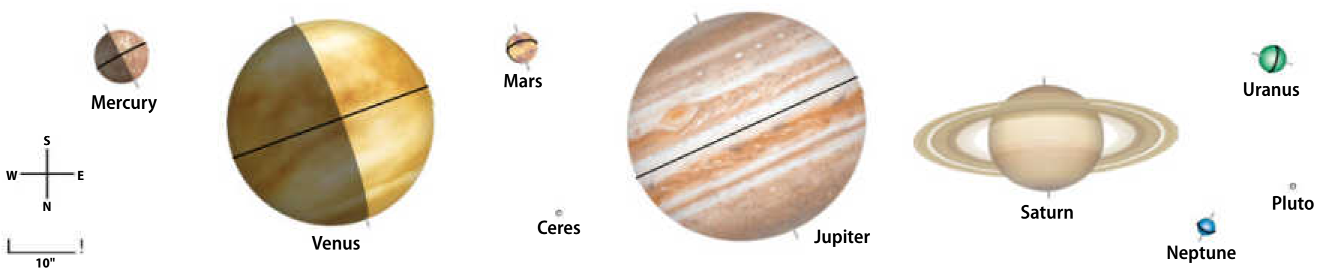
BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

The planets in October 2015



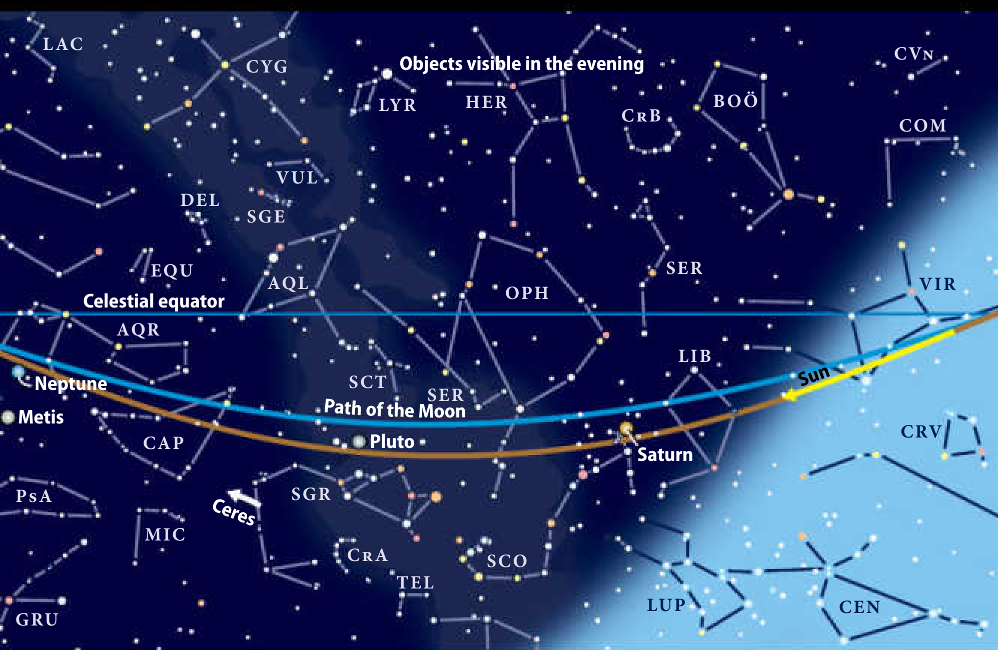
The planets in the sky

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets for the dates in the data table at bottom. South is at the top to match the view through a telescope.



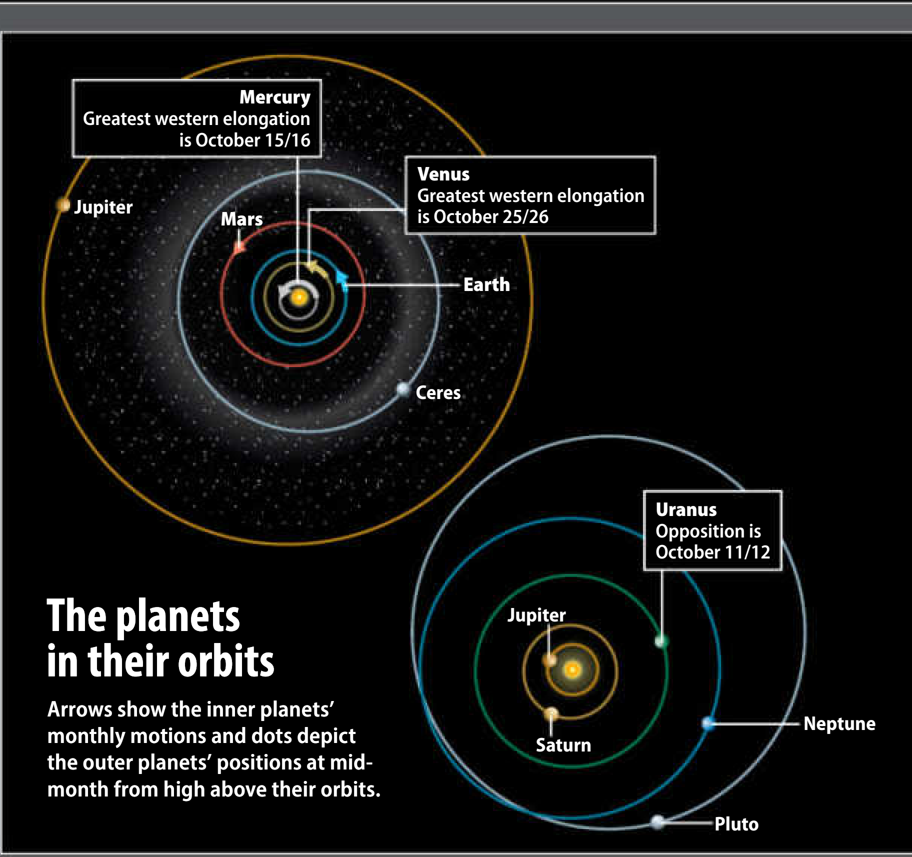
Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	Oct. 15	Oct. 15	Oct. 15	Oct. 15	Oct. 15	Oct. 15	Oct. 15	Oct. 15	Oct. 15
Magnitude	–0.5	–4.6	1.8	8.9	–1.8	0.6	5.7	7.8	14.2
Angular size	7.2"	27.4"	4.1"	0.5"	32.0"	15.5"	3.7"	2.3"	0.1"
Illumination	49%	44%	96%	97%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.940	0.608	2.312	2.691	6.154	10.731	18.986	29.236	33.094
Distance (AU) from Sun	0.309	0.722	1.659	2.969	5.400	10.000	19.982	29.962	32.965
Right ascension (2000.0)	12h14.0m	10h26.1m	10h56.2m	20h06.8m	11h00.3m	16h01.4m	1h08.0m	22h36.6m	18h55.1m
Declination (2000.0)	0°12'	8°26'	8°14'	–30°18'	7°24'	–18°54'	6°30'	–9°39'	–21°04'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.



Early evening

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line. **Note:** Moons vary in size due to the distance from Earth and are shown at 0h Universal Time.

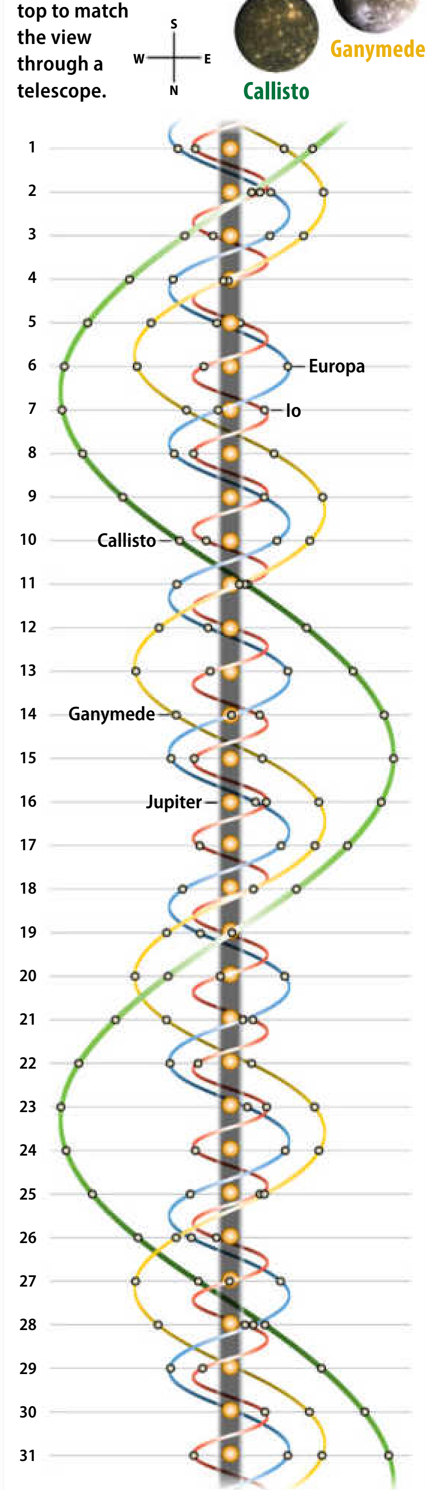


The planets in their orbits

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at mid-month from high above their orbits.

Jupiter's moons

Dots display positions of Galilean satellites at 6 A.M. EDT on the date shown. South is at the top to match the view through a telescope.



ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

— *Continued from page 37*

WHEN TO VIEW THE PLANETS

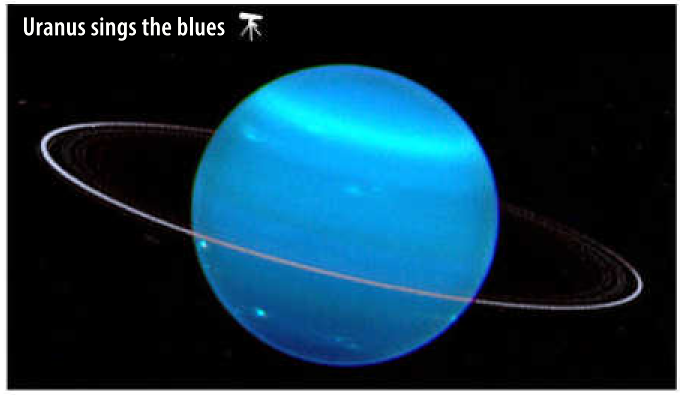
EVENING SKY	MIDNIGHT	MORNING SKY
Saturn (southwest)	Uranus (south)	Mercury (east)
Uranus (east)	Neptune (southwest)	Venus (east)
Neptune (southeast)		Mars (east)
		Jupiter (east)
		Uranus (west)

darkness falls and climbs highest in the south around 11 P.M. local daylight time. It reaches the same peak position two hours earlier by month's end.

Neptune glows at magnitude 7.8, so you'll need binoculars or a telescope to spot it. The planet lies 4° to 5° southwest of 4th-magnitude Lambda (λ) Aquarii. Once you locate this star, scan to the southwest for 5th-magnitude Sigma Aqr. On October 1, Neptune stands 2° northeast of Sigma and 0.9° due east of a 7th-magnitude sun. The planet's motion carries it west-southwest this month, and by the 31st, it has cut the gap to this latter star in half. Target Neptune through a telescope, and you'll see a blue-gray disk that spans 2.3".

Head one constellation east of Neptune, and you'll be in Pisces, the home turf of **Uranus**. The seventh planet reaches opposition the night of October 11/12, which means the world lies opposite the Sun in our sky and remains visible throughout the night. Uranus also lies closest to Earth (a still substantial 1.8 billion miles away) and shines brightest (magnitude 5.7) at opposition. You can spot it with naked eyes from under a dark sky, though binoculars make the task much simpler.

You'll have an easier time viewing Uranus if you wait until midevening when it climbs reasonably high in the east-southeast. Use the Great Square of Pegasus as a guide. Draw an imaginary line from Beta to Gamma (γ) Pegasi, the top and bottom of the asterism,



LAWRENCE SROMOVSKY (UNIVERSITY OF WISCONSIN)/ W. M. KECK OBSERVATORY

Methane in Uranus' atmosphere absorbs red light, giving the planet a distinctive bluish hue through amateur instruments. This Keck Telescope image also records atmospheric structure and a faint ring.

respectively, on October evenings. Then continue the line and steer slightly left to pick up Delta (δ) and Epsilon (ε) Piscium. The planet lies in the same binocular field as these two 4th-magnitude stars.

On October 1, Uranus stands 2° east-southeast of (below) Epsilon. The planet tracks westward all month but covers only about 1° of sky. It spends the last three weeks of October traveling just north of a conspicuous triangle of 6th-magnitude stars. When viewed through a telescope, Uranus shows a 3.7"-diameter disk with a distinctive blue-green color.

As the outer planets wheel into the western sky on October mornings, the eastern sky comes alive with bright planets. Three of these worlds congregate near one another in Leo the Lion. **Venus** shines brightest at magnitude –4.6 trailed by **Jupiter** at magnitude –1.8 and **Mars** at magnitude 1.8.

On October 1, Venus rises around 3:30 A.M. local daylight time followed by Mars just after 4 A.M. and then Jupiter a half-hour later. Seventeen degrees separate the three in the predawn darkness. As pretty as this morning scene is, however, it

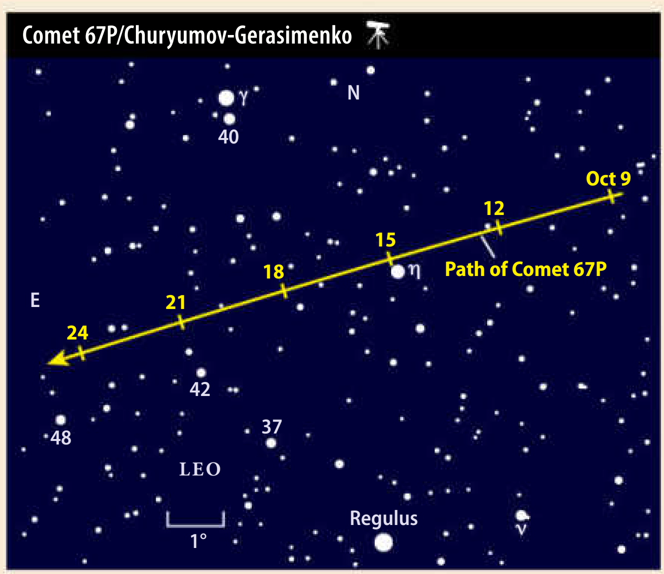
COMETSEARCH

Set your sights on Rosetta's quarry

The comet making the biggest splash in 2015 has to be 67P/Churyumov-Gerasimenko, the two-lobed object seen in stunning detail by the European Space Agency's Rosetta spacecraft. Observers should get some of their best views of the comet in October. If we're lucky, the dirty snowball may outburst and glow at 10th magnitude, within reach of a 4-inch telescope under a dark sky. If not, 67P could be 12th magnitude and require an 8-inch or larger aperture.

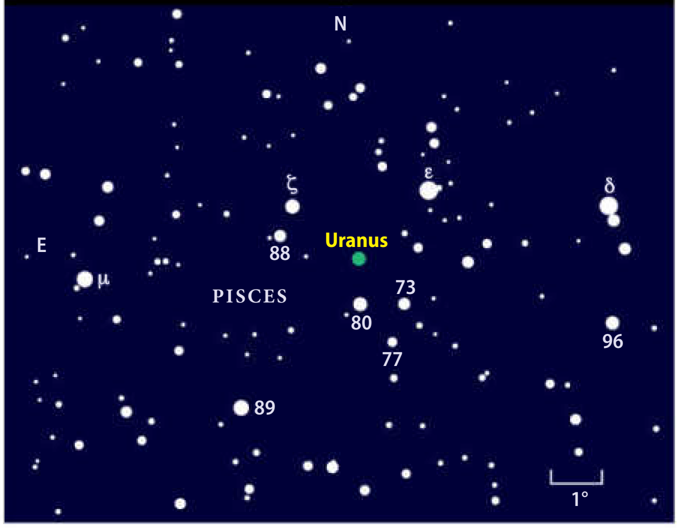
The comet resides among the background stars of Leo, near the splendid gathering of bright morning planets. Start watching October 9 when a slim crescent Moon joins the lineup. But this is just a prelude to a suite of dazzling dawns. Comet 67P lies a short hop from Venus and Regulus, and passes a mere 16' north of magnitude 3.5 Eta (η) Leonis on the 15th.

To see the most detail, pump up the magnification past 100x. Although the extra power spreads out the light a bit, it is the only way to notice that 67P's eastern flank sports a well-defined edge where the solar wind interacts with the comet's escaping gas.



Leo the Lion's head offers several bright guide stars to steer you toward the active comet currently under surveillance by the Rosetta spacecraft.

Icy giant glows brightly



Uranus lies among the stars of southern Pisces at opposition October 11/12. Find it with naked eyes or binoculars; a telescope shows its small disk.

only gets better as the planets close in on one another.

A waning crescent Moon joins the trio October 8. The spectacular gathering features Venus just 4° east of Luna with Mars and Jupiter 9° and 13° farther east, respectively. Leo's brightest star, 1st-magnitude Regulus, adds to the display from a spot 2.5° to Venus' northeast. The following morning, an even slimmer crescent Moon forms a compact triangle with Mars and Jupiter as Venus rides above.

On October 17, Mars passes less than a Full Moon's width north of Jupiter while Venus stands 6.7° west of the pair — and closing. The 23rd finds Mars and Venus 4.5° apart with Jupiter midway between.

Three mornings later, Venus slides 1.1° south of Jupiter. Although skygazers relish any conjunction involving the two brightest planets, this morning scene proves particularly dazzling because the two appear so high in the sky. In a grand coincidence, Venus also attains greatest elongation on the 26th, when it stands 46° west of the Sun and appears more than 25° high as twilight begins. The three planets all reside within a 3.5°-wide circle.

Another pretty vista beckons October 28 when Mars and Jupiter appear 4.5° apart with Venus hanging between the two. By October's final morning, Jupiter stands highest while Venus has closed to within 1.4° of Mars. The latter two will experience a close conjunction of their own in early November.

October's morning show looks great with naked eyes, binoculars, or a telescope. With the higher magnification a scope provides, you can track dramatic changes in Venus' appearance. On October 1, Earth's neighbor spans 33" and appears 35 percent lit; by the 31st, it measures 23" across with the Sun illuminating just over half of its disk.

Jupiter's apparent diameter grows from 31" to 33" in October, and the world should show plenty of atmospheric detail. Unfortunately, Mars reveals a featureless disk 4" across.

You'll have to wait until twilight begins for a view of October's final morning planet. **Mercury** reaches greatest western elongation the night of October 15/16, when it stands 18° from the Sun and climbs 8° above the eastern horizon 45 minutes before sunrise. Five days earlier (on the 11th), catch Mercury just 1° from the waning crescent Moon. The pair rises some 80 minutes before the Sun.

The innermost planet lies in Virgo, one constellation east of Leo and its three planets and thus lower in the predawn sky. Mercury shines at magnitude 0.2 on the 11th, brightens to magnitude –0.6 by greatest elongation, and gains a bit more luster by month's end. A telescope reveals the inner world's changing form. On the 11th, Mercury's disk spans 8" and appears one-third illuminated. By the 31st, its diameter has shrunk to 5" and its phase has waxed to more than 90 percent lit.

LOCATING**ASTEROIDS**

A bright asteroid swims with the Whale

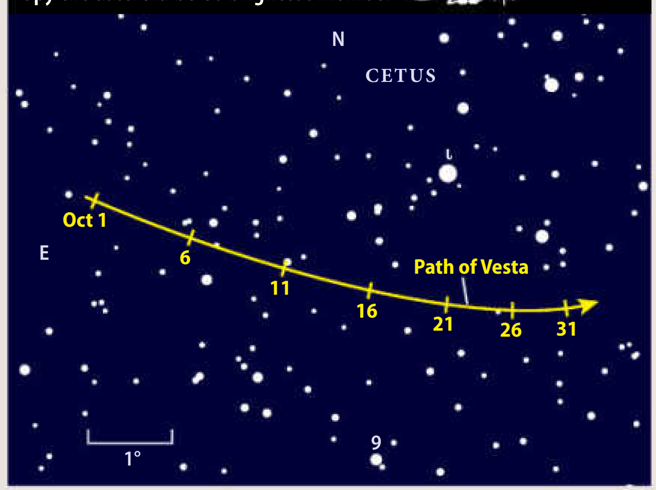
Although asteroid 4 Vesta fades from magnitude 6.2 to 6.8 during October, it remains the brightest minor planet. You'll find it an easy target through binoculars from the suburbs and barely within reach of naked eyes from a dark site early in the month. Having reached opposition in late September, it remains visible nearly all night, climbing highest in the south around midnight local daylight time.

To find Vesta, first locate magnitude 2.0 Beta (β) Ceti. Then point your binoculars 10° to the north-northwest at magnitude 3.5 Iota (ι) Ceti. During the latter half of October, Vesta will be the brightest point of light south of Iota.

As a bonus for observers at mid-northern latitudes, Vesta lies within the same binocular field as the similarly bright geostationary satellites. These satellites orbit directly above Earth's equator at an altitude of 22,236 miles. They can get as bright as 4th magnitude, and in some constellations like Cetus, the extra "stars" look obvious to experienced observers.

From mid-northern latitudes, the satellites appear some 5° to 7° below the celestial equator, or a little above Vesta. The satellites appear brightest in October and early February when the Sun lies at the same declination, allowing mirror-like reflections off their solar panels.

Spy the asteroid belt's brightest member



Use magnitude 3.5 Iota (ι) Ceti to home in on Vesta, the most obvious point of light just south of this star during the latter part of October.

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

No country for old telescopes

Van Vleck Observatory sits on Foss Hill on the campus of Wesleyan University in Middletown, Connecticut. OLIVIA DRAKE/WESLEYAN UNIVERSITY

At Wesleyan University's Van Vleck Observatory, a century-old 20-inch refractor is experiencing a rebirth. The fate of many other classic refractors is not so bright.

by Joshua Sokol

It was October 1998 when Chris Ray's footsteps first echoed in the dome overlooking Andrus Field — the central lawn — at Wesleyan University in Middletown, Connecticut. Above him loomed a 28-foot-long (8.5 meters), 2-ton refracting telescope that had seen better days.

Ray, an expert in museum restoration, could see that the instrument's bearings had rusted. Paint was peeling off the scope. "I just had a sense of desolation looking at this telescope," he says. "It looked abandoned."

It had once been cutting edge. In the 19th and early 20th centuries, long refractors like the one at Wesleyan were points of pride for dozens of American universities — chances to explore nature at its grandest scales and to loudly signal a commitment to that endeavor. But the second half of the 20th century saw big refractors stagger into obsolescence.

Now the institutions that house these relics face tough choices. Although refractors offer crisp views of celestial wonders like Saturn, they're too outdated to draw research grants from major sources like the National Science Foundation. Often, they hog prime campus real estate. Sure, they're historical — but they're also hard to use, even dangerous. And renovating one can cost half a million dollars or more.

Joshua Sokol *is a science writer based in Boston. Clinically afraid of hardware, he was a data analyst for the Hubble Space Telescope — and that was close enough.*

For much of the past decade, Ray and his business partner, Fred Orthlieb, a retired engineering professor at Swarthmore College in Pennsylvania, have traveled the country restoring these defunct marvels. Roy Kilgard, a research and support astronomer in charge of the public outreach program at Wesleyan, invited Ray to visit, and his first sight of the refractor was a reminder that not all historic telescopes die a dignified death. Even fewer are granted second chances.

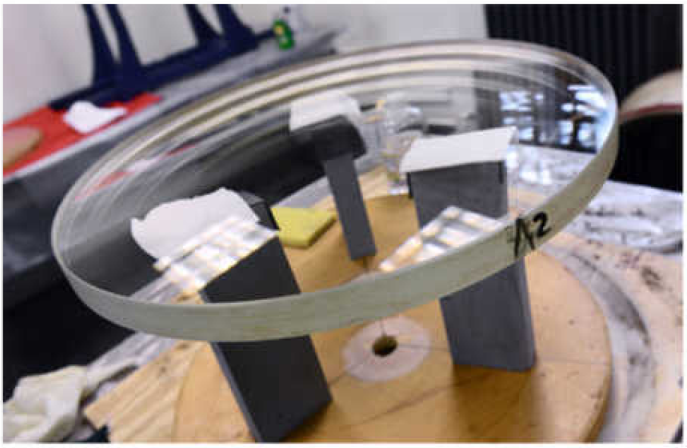
At Wesleyan, a storied instrument stood at a crossroads, where a final decision to renovate or replace had to be made. "At some point, a lot of these places are just going to shut the doors," Orthlieb says. "Some already have."

The age of giant refractors

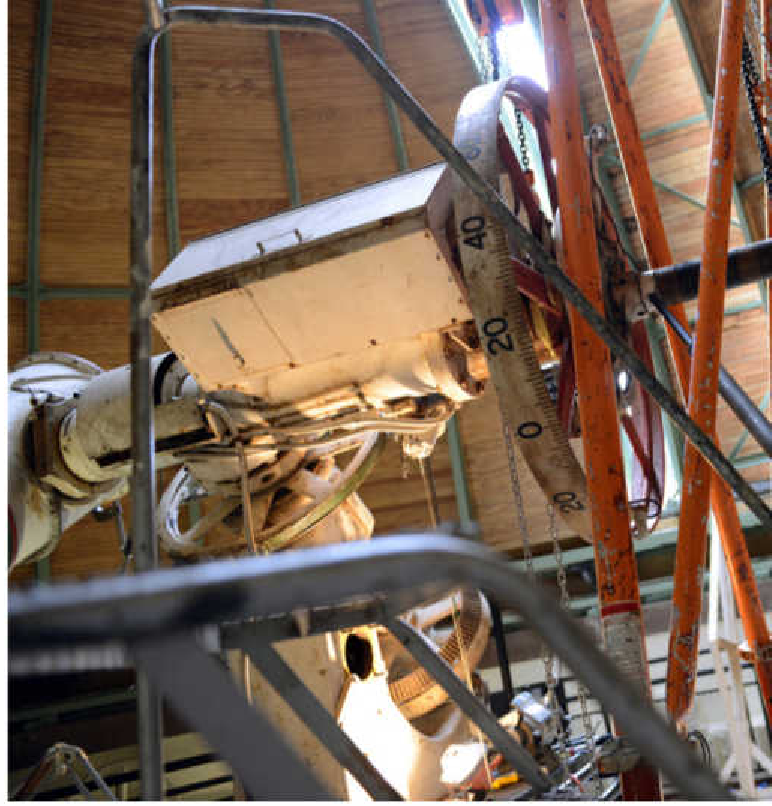
Wesleyan's refractor is exactly what the word *telescope* brings to most people's minds. A lens focuses light down the length of a tube, which teeters at its middle on a counterbalanced mount. Gears in the mount let the telescope point at and track the sky. At the end of the scope, a photographic plate or an eyepiece for visual observing intercepts the converging light from the primary lens.

Refractors, seen even now on college seals as a stand-in for *science*, were half lab equipment, half status symbol. Products of the Enlightenment, they came to represent modernity itself. In 1764, Harvard University's scientific instruments were lost in a fire; none other than Ben Franklin went on a shopping spree in London and shipped back a set of new, shiny brass refractors.

This is how Wesleyan University's 20-inch refractor looked in May 2014, just before it would be taken down for restoration. Workers already had refinished the dome's interior and floor.
OLIVIA DRAKE/WESLEYAN UNIVERSITY



The rear element of the Wesleyan scope's 20-inch Alvan Clark doublet lens rests on blocks after the restoration team removed it from its cell and Chris Ray initially washed it. The "V" on the lens' side marks the forward direction. OLIVIA DRAKE/WESLEYAN UNIVERSITY



Fred Orthlieb strains to unscrew the 20-inch refractor's right ascension counterweight bar from its threaded socket at the end of the declination axis. The bar itself weighs 200 pounds (90 kilograms). OLIVIA DRAKE/WESLEYAN UNIVERSITY

By the 19th century, as technological advances allowed glass lenses and the refractors built with them to get bigger and better, American universities itched to get their hands on them. "To appear legitimate on a world stage, you had to have a telescope," says David DeVorkin, a historian of astronomy at the Smithsonian Institution's National Air and Space Museum.

At Wesleyan, three generations of telescopes trace to this era. First, the university bought a 6-inch, 7-foot-long (2m) refracting telescope from a craftsman in Paris in 1836, following Yale and preceding Harvard as one of the first American universities to get its hands on one. Astronomy rose in the public consciousness while also syncing with the liberal arts ideal. Then American telescope makers, long overshadowed by their peers across the Atlantic, got in on the trend in the years after the Civil War.

Foremost among them was Alvan Clark & Sons, a workshop in Cambridgeport, Massachusetts, renowned for precision and artistry alike. In 1868, Wesleyan stocked its observatory with Clark instruments, including a 12-inch, 15-foot-long (4.6m) scope that later passed to Miami University and then into private hands. And as the century progressed, Clark lenses bulged against the limits of engineering. On five occasions, the Clarks sculpted the biggest telescope lens in the world, often breaking their own record and necessitating gargantuan tubes to match the long focal lengths.

Twenty-six inches. Thirty inches. Thirty-six inches. Then, in 1897: a 40-inch lens for Yerkes Observatory in Wisconsin. The largest lens ever used for astronomical research, it is so huge that the light it focuses converges 62 feet (19m) away.

As a small liberal arts school, Wesleyan was priced out of the competition for these behemoths. But when the university set out to acquire a bigger, better telescope in the 1910s, it looked to the same trusted brand. The lens, ground by hand and tested by eye at Alvan Clark & Sons, arrived late but 20 inches in diameter — an inch and a half bigger than ordered. It was an auspicious start.

Measuring the stars

Before an assembled crowd in June 1916, astronomer Frederick Slocum dedicated Wesleyan's Van Vleck Observatory, which was named for John M. Van Vleck, who taught astronomy and mathematics at the university from 1853 to 1912. Although the Clark lens had not yet arrived on campus, the building already was impressive. Perched inside its spotless dome on Foss Hill, the lens-less telescope sprawled above a movable floor (courtesy of the Otis Elevator Company) that could rise or fall to bring observers level with the eyepiece.

Astronomical research and the teaching of students would go hand in hand at Wesleyan, Slocum told his audience. But in an age of giant telescopes, even a 20-inch refractor was only modest. Worse still, New England's weather is notoriously dreadful for astronomy.

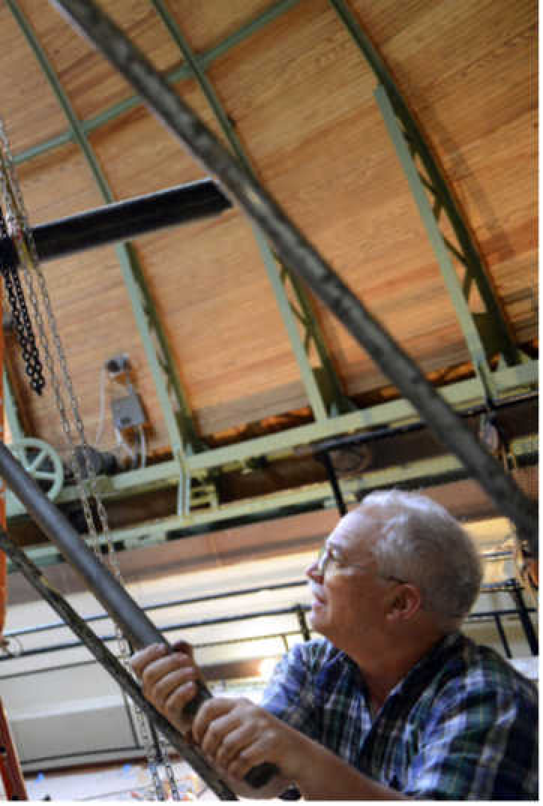
To make an impact, the Van Vleck Observatory would have to focus on a single fundamental question. By collaborating with Yerkes, England's Royal Greenwich Observatory, and a consortium of other schools, Wesleyan researchers would measure parallaxes — a way to gauge how far away stars are through the tiny displacements in their positions caused by Earth's orbital motion around the Sun. The astronomers would find the distances to the stars, Slocum said — and that's exactly what they did.

From the 1920s until the 1990s, when the European Hipparcos satellite took up the baton by measuring precise distances to more than 100,000 stars, Wesleyan's refractor toiled away at the problem. It was used to train generations of young astronomers and for fun and outreach, too: In the 1950s, popularizer Walter Scott Houston peered through it to write his "Deep Sky Wonders" column for *Sky & Telescope*.

Astronomer Bill Herbst, a professor at Wesleyan and former director of Van Vleck Observatory, recalls the halcyon days. When he arrived at Wesleyan in 1978, the telescope was still a parallax factory, still in its prime, operating under the careful guidance of Director Arthur Upgren.

But decades of old-fashioned astrometry, the careful by-hand measurement of the distances between stars on photographic plates, came at a cost. For the results to stay consistent, the telescope couldn't be modified. "It was protected like it was made of gold," says Herbst.

No single development killed the research use of the Wesleyan refractor and its peers around the country. Instead, National Science Foundation funding slowly dried up. Reflecting telescopes,



THE BIGGEST REFRACTORS IN THE UNITED STATES

The United States currently has 11 refracting telescopes sporting primary lenses 20 inches in diameter or larger, topped by the 40-inch scope at Yerkes Observatory in Wisconsin. All of them remain under control of their original owners except for the one at Roper Mountain Science Center in Greenville, South Carolina, which started out as the main instrument at Princeton University's Halstead Observatory in New Jersey.

Name	Location	Lens diameter	Built
Yerkes Observatory	Williams Bay, Wisconsin	40 inches	1897
James Lick Telescope Lick Observatory	Mount Hamilton, California	36 inches	1888
William Thaw Telescope Allegheny Observatory	Pittsburgh, Pennsylvania	30 inches	1914
U.S. Naval Observatory	Washington, D.C.	26 inches	1873
Leander McCormick Observatory	Charlottesville, Virginia	26 inches	1884
Lowell Observatory	Flagstaff, Arizona	24 inches	1894
Sproul Observatory	Swarthmore, Pennsylvania	24 inches	1911
Roper Mountain Science Center	Greenville, South Carolina	23 inches	1881
Chamberlin Observatory	Denver, Colorado	20 inches	1891
Chabot Observatory	Oakland, California	20 inches	1914
Van Vleck Observatory	Middletown, Connecticut	20 inches	1922

which use mirrors and not lenses to collect light, became more and more ubiquitous largely because craftsmen could make them much bigger. Photographic plates were being changed out for modern camera chips. And the very untouchability that kept the Wesleyan scope's measurements stable over time also deferred maintenance, which aided its undoing.

Old telescopes are like old automobiles, says Ray: Without careful attention to preservation, time can kill them. They must be lubricated and not allowed to rust. The domes can't leak. The lenses should be taken out and cleaned every three years or so.

Yet another threat is botched surgery. In the late 1960s, an engineering firm put Wesleyan's telescope under motorized control. The company replaced the original hand-turned wheels that moved the scope and then threw out those trustworthy old parts. Many of the updates have since fallen to shreds, leaving the Wesleyan refractor working but a shell of its original self.

Only the dedicated work of folks like Kilgard had kept the scope operational, though not as an instrument for serious science. Still, students taking introductory astronomy classes used the 20-inch during observing sessions, and members of the general public got to peer through its ancient glass during monthly viewing nights hosted by the Astronomical Society of Greater Hartford.

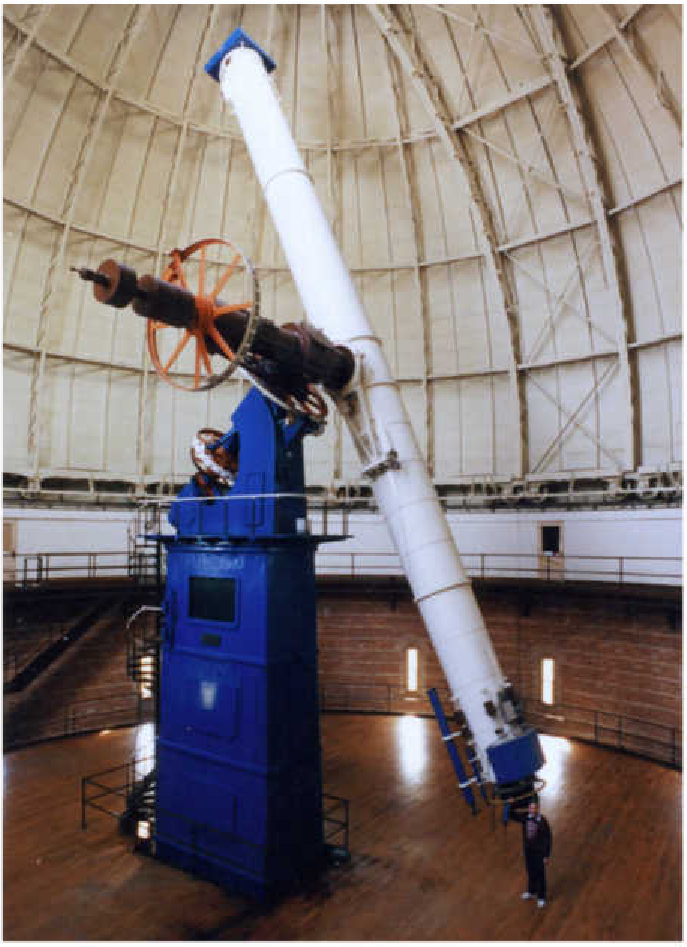
A lost generation?

Looking around the country, old refractors like the one at Wesleyan face a diversity of fates. They can be discarded entirely, with the observatories torn down and the instruments shelved or sold to private collectors. Storied astronomy departments at the University of Pennsylvania and Princeton University followed this path, as did Beloit College in Wisconsin, whose observatory building now survives only as limestone blocks in a retaining wall.

They can haunt as dusty crypts few ever enter. At Swarthmore College, the famous 24-inch Sproul refractor (see "Triumph to tragedy" on p. 48) sits unused inside a green dome. Orthlieb and Ray tried to fix it, but renovation plans were scrapped when the last astronomer loyal to it died in the early 2000s.

With wrench in hand, Julian Dann works inside the rear end of the optical tube assembly's back half. The four bronze rods seen here originally provided about 3 feet (1 meter) of coarse focus. OLIVIA DRAKE/WESLEYAN UNIVERSITY

Becca Hanschell removes fasteners from the forward part of the optical tube assembly's back half so she can take out the electrical cable shields inside the tube. OLIVIA DRAKE/WESLEYAN UNIVERSITY



The world's largest refractor, a 40-inch behemoth, resides at Yerkes Observatory in Williams Bay, Wisconsin. Astronomer Kyle Cudworth provides a sense of its mammoth scale. RICHARD DREISER/YERKES OBSERVATORY

TRIUMPH TO TRAGEDY

Peter van de Kamp, seen here in 1976, believed he had found at least one planet circling Barnard's Star through the 24-inch Sproul refractor at Swarthmore College.

AIP EMILIO SEGRÈ VISUAL ARCHIVES, JOHN IRWIN SLIDE COLLECTION

In conversations with historians, the consensus is clear: No story of 20th-century refractors can ignore the saga of Peter van de Kamp. It's a tale in which Wesleyan's Van Vleck refractor plays a pivotal role.

In the 1960s, the Dutch-born van de Kamp made headlines worldwide. He claimed to have discovered the first extrasolar planet (or planets) by measuring slight wiggles in the position of the nearby red dwarf Barnard's Star through the 24-inch Sproul refractor at Pennsylvania's Swarthmore College. It fell to observatories like Wesleyan's with similar telescopes to confirm the discovery.

They couldn't. At Wesleyan, professor Heinz Eichhorn saw no such planet — it just didn't exist. Perhaps the lenses at Swarthmore had shifted subtly during a 1949 cleaning, creating a spurious wiggle. Van de Kamp, by all accounts a lovely man, went to his grave stubbornly insisting he was right.

Even though Wesleyan's telescope had helped resolve the debate, the reputation of refractors as precise instruments took a big hit — one from which they perhaps never recovered. The Smithsonian Institution's David DeVorkin goes even further: "If I were really wanting to be provocative, I would say van de Kamp helped to kill the long-focus refractor." — *J. S.*

YERKES OBSERVATORY

Alvan Graham Clark (left) poses as assistant Carl Lundin polishes the 40-inch lens that would become the heart of the Yerkes Observatory refractor.

They can malinger as sources of shame. "Our telescope has been forgotten for over 20 years," writes the head of the physics department at Brooklyn College in New York in response to a request to visit the school's observatory. "An exterior hole in the building let the birds in and completely messed up the room. There is nothing respectable to see."

Or they can be granted new lives. In the 1970s, with its observatory in a state of decay, Brown University in Rhode Island considered selling the lot to McDonald's. Now, thanks to the efforts of volunteers and a 1990s restoration, guests pack public open houses waiting their turn to look through the 12-inch Ladd refractor.

A rebirth of hope

In June 2014, Ray returned to Middletown with Orthlieb. Their mission: to save the Wesleyan refractor. Herbst had hired the two after convincing university administrators to reinvest in the telescope. Given that the observatory is an icon of the campus, the administration realized it would be an embarrassment to let the big white dome and the instrument inside it rust away.

"Some telescopes get saved; all too many don't," says Bart Fried, founder and president of the Antique Telescope Society, an organization of historians, engineers, and other enthusiasts.

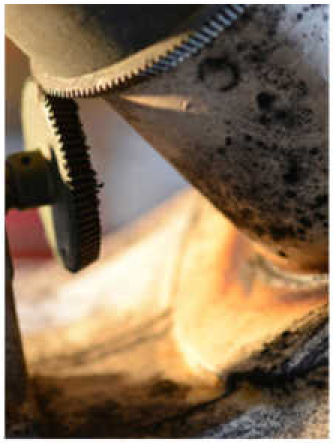
"They're almost too big to throw away," he continues, referring to the giant refractor at Yerkes Observatory and its smaller cousins at Swarthmore and Wesleyan. "You can't inconspicuously sweep Yerkes under the rug. Or Sproul under the rug. Or Van Vleck under the rug."

But the decision to bring back an old university refractor isn't as simple as it might seem. It costs at least a few hundred thousand dollars. It entails rehabbing a building, fixing the scope, painting, and meeting electrical and safety codes. It requires hiring engineering firms or expert enthusiasts like Ray and Orthlieb. And all of this is for what's essentially a giant obsolete piece of lab equipment.

"I can't get hysterical about the loss of every observatory," says Sara Schechner, a historian and curator of Harvard's Collection of Historical Scientific Instruments, in an office that features no fewer than five globes depicting the celestial sphere. Clearly she's a partisan: Schechner married her husband in the observatory at Wellesley College in Massachusetts.

She is sympathetic to the calculus facing college administrators, who have to weigh the cost of refurbishing an old refractor against

buying a newer, user-friendly instrument. In addition, any institution with a large refractor must worry about liability. If it becomes unbalanced, even a healthy refractor can swing with punishing momentum. "The guy before me broke his neck," says DeVorkin, whose first job had him operating the 36-inch refractor at Lick Observatory in California, then the world's second largest. Steering a telescope by hand isn't exactly risk-free.



OLIVIA DRAKE/WESLEYAN UNIVERSITY

These corroded gears originally drove a dial on Wesleyan's 20-inch refractor that showed where the scope was pointing.

It's also hard to strike a balance between authenticity and pragmatism. A telescope restored with historical accuracy, including authentic drives and setting circles, has a much steeper learning curve than modern computerized systems. And even if the restoration faithfully reproduces the old instrument, it's not a great teaching tool for future astronomers — the field has moved on.

On the other hand, a new telescope is much less romantic. No whirring gears, no hand-turned wheel that drives the scope into position, no steampunk brass — and crucially, in the age of modern cameras and other instruments, often no eye-to-tube experience.

The way Orthlieb and Ray fix telescopes — what they are doing at Wesleyan — is often something in between. "A kind of Frankenstein monster" is what Schechner calls it. But in this fix, Orthlieb and Ray are transforming the true "Frankenstein monster" — the one created by the relatively clumsy 1960s modernization — into a hybrid featuring classic major components (including the Clark optics, optical tube assembly, and pier) married to a modern and sophisticated operating system.

Renovating the telescope like this may sound like degrading it, says Ray. But in bright urban areas, the days of pointing a telescope toward a familiar constellation to home in on a target are long gone. Even in Middletown, which is darker than many cities, modern technology will simplify and speed up observing.

The new old Wesleyan refractor, when it emerges, will be a careful compromise of history and pragmatism. The goal is to preserve the telescope's past while ensuring its usability for another 100 years. "It's going to be a telescope that's pretty easy to use," says Herbst. "It's going to provide really unparalleled views."

The restoration itself offers unique opportunities, too. Decades of Wesleyan undergraduates have used the telescope. Precious few have seen its inner workings. And fewer still have helped shepherd it from senescence to a hopeful future.

Return of an icon

Work on the restoration began in June 2014. At the start of the project, the telescope hung by ropes as a small team prepared to dismantle it. Orthlieb and undergraduate students Becca Hanschell and Julian Dann took out alternating screws to avoid straining the structure. They then pulled out a stubborn cylinder that weighed more than 200 pounds (90 kilograms). "We had to ease it out by crowbars, banging it," Hanschell recalls. "It comes loose. One bang, and it goes '*pop!*' And it just swings. It was kind of scary."

By June 2015, the restoration of the 20-inch Van Vleck refractor was nearing completion. Here, the repainted front half of the optical tube assembly appears in the foreground; the renovation team expects to install it by the end of August. LAURIE KENNEY/WESLEYAN UNIVERSITY

Ray and Orthlieb then made exacting measurements and took the scope apart. Over the next few months, Hanschell and Dann worked under Orthlieb and Ray's guidance. Although the students had studied astronomy, not engineering, they caught on fast.

On sunny days, Hanschell and Dann kept the slit of the dome open to take advantage of the natural light. The sunbeam coming through the open slit turned slowly, a sundial to mark the time of day. On rainy days, they'd turn on all the lights, even the emergency ones, to brighten the closed space. It was still dim. They could hear the rain pounding on the outside of the dome. "It'd feel like you were beneath this huge sea," says Dann.

Over the summer, they painted the scope's components white instead of black. Ray came briefly, too. He spent his visit hunched over the Clark lens carefully, lovingly cleaning rust away from the edges and then polishing the glass.

By summer's end, Hanschell and Orthlieb had put much of the telescope back together. After returning to their workshop at Swarthmore, Orthlieb and Ray set to work fabricating the scope's new drive gears.

Wesleyan's refractor is now en route to a happy exhumation, currently scheduled for completion in time for the observatory's centennial in 2016. But what happens to telescopes elsewhere is up in the air. For now, Orthlieb, Ray, and others with the Antique Telescope Society are there for the universities that want them. Like the telescopes they fix, the gears still turn. "We're antiquarian — we're antiques," says Orthlieb. "But our brains are still alive, and we know how to do this stuff."

TO SEE SOME TIME-LAPSE VIDEOS OF THE RESTORATION WORK AT VAN VLECK OBSERVATORY, VISIT **www.Astronomy.com/toc.**

WHERE'S *SNOOPY?*

Q: WHAT BECAME OF THE DISCARDED LUNAR MODULES FROM THE APOLLO MISSIONS?

James Jarvis, *San Francisco*

The crew of Apollo 10 shot this image of the lunar module *Snoopy*, following its separation from the command module *Charlie Brown*. *Snoopy* now orbits the Sun in an unknown location. NASA

A: All but one of the Apollo program's used lunar modules either crashed into the Moon's surface or burned up in Earth's atmosphere. Apollo 10's lunar module, *Snoopy*, is still out there, drifting aimlessly around the solar system, waiting for some future exo-archaeologist to snatch it up for display at the Smithsonian.

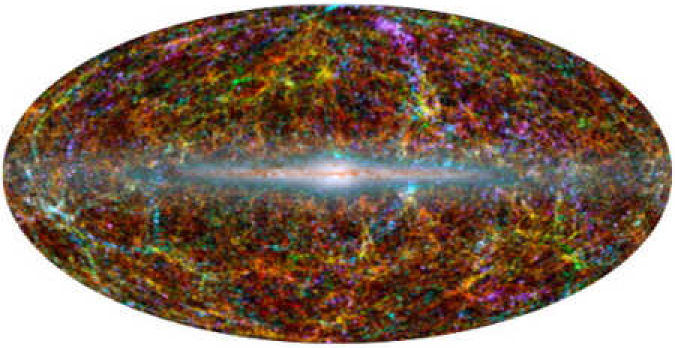
The mission was designed as a rehearsal for the main event on the Moon, but it set records of its own. History glazes over Apollo 10 because of the significance of what followed; however, the crew completed the same tasks as Apollo 11 (minus landing on the Moon).

And they used *Snoopy*, the lunar module, as well as *Charlie Brown*, the command module, to travel farther and faster than any humans have before or since.

During the mission, *Snoopy* was jettisoned into space as planned and would have entered orbit around the Sun. However, its location remains a mystery despite efforts by amateur astronomers to search for it using the last known 1969 orbital coordinates. They identified a number of target sites, but so far they've been unsuccessful.

Interestingly, many of the other landers' exact lunar impact sites — including Apollo 11's *Eagle* — are also a mystery that future space explorers may someday find and excavate, like underwater archaeologists uncovering Amelia Earhart's Lockheed Electra.

Eric Betz
Associate Editor



The Two Micron All-Sky Survey was designed to map the distribution of galaxies and dark matter in our universe. Here, blue objects are closest to our galaxy and red are the most distant. T.H. JARRETT (IPAC/SSC)

Q: OUR SOLAR SYSTEM IS IN AN OUTER SPIRAL ARM OF THE MILKY WAY, BUT DO WE KNOW WHERE OUR GALAXY IS WITHIN THE UNIVERSE?

Paul Goldblatt
Huntington, New York

A: We know a lot about our Milky Way Galaxy's location in the universe thanks to efforts to map the distances to nearby galaxies. Our galaxy is a member of the Local Group — a small collection of galaxies, of which the Milky Way and Andromeda galaxies are the two largest. About 50 smaller galaxies surround them.

The Local Group is located on the outskirts of the Local Supercluster (often called the Virgo Supercluster), and the Virgo Cluster sits at the center. This collection of up to 2,000 galaxies includes some that are much more massive than the Milky Way.

Using an everyday analogy, if galaxies were houses, you could think of the Virgo Cluster as the big city in a county called the Local Supercluster. That makes our Local Group a small rural town.

On scales bigger than a supercluster, the universe is homogeneous and isotropic. That means it is roughly the same at all locations and in all directions. There is no center to the universe, which current models say is infinite in size, though every "observer" is at the center of their own finite-sized "observable universe" (which has a radius of the distance light has traveled since the Big Bang).

This also explains why maps of the universe often make it look like the Milky Way is at the center.

Karen Masters
Institute of Cosmology and Gravitation
University of Portsmouth
United Kingdom

Q: HOW DO ASTRONOMERS USE CEPHEID VARIABLES TO MEASURE DISTANCES?

Richard Lynch
Essex Junction, Vermont

Messier's "lost" object, M102, has been a subject of controversy since the catalog was first published in 1781. Some astronomers think spiral galaxy NGC 5866, imaged here by the Hubble Space Telescope, might be the true target. NASA/ESA/ THE HUBBLE HERITAGE TEAM (STScI/AURA)

A: The simple answer is that the intrinsic brightness of these variable stars is strongly tied to their period. This is the famous period-luminosity relationship discovered by Henrietta Leavitt more than a century ago.

So astronomers can predict the absolute magnitude (i.e., the mean intrinsic luminosity) of any given Cepheid by measuring the time it takes to rhythmically change its brightness. By observing the apparent luminosity, dimmed by the inverse square law of light traveling across the vast reaches of space, and comparing this with the predicted luminosity, astronomers can calculate the distance to that star.

Why should there be a period-luminosity relationship in the first place?

The answer involves some simple physics combined with a little bit of geometry. At the heart of it is gravity. Most stars, including Cepheids, are in hydrostatic equilibrium where there is a balance between the inward force of gravity and the outward pressure of the energy the star radiates.

As stars evolve, that equilibrium can be perturbed and in some circumstances leads to stable oscillations, as in the case of Cepheids. For mechanical systems (including those regulated by gravity), the natural period of oscillation is largely controlled by the average density, which is mass divided by volume (or equivalently the cube of the radius).

The bottom line is that low-density stars have longer periods. And variables like Cepheids also tend to have larger radii. Larger radii translate into larger surface areas, which for a fixed surface brightness means higher luminosity. Longer-period Cepheids will then have higher luminosities. Periods predict luminosities.

Barry Madore
Carnegie Observatories
Pasadena, California

Q: MESSIER'S 102ND ENTRY IS KNOWN AS THE LOST MESSIER OBJECT. HAS THERE BEEN ANY AGREEMENT ON WHAT THIS M OBJECT MIGHT BE?

William Shackelford
Bangor, Maine

A: Before Charles Messier handed in the final supplement of his catalog, which was published in 1781, his contemporary, Pierre Méchain, supplied a number of new objects for his consideration. Messier observed all but three of them before his publishing deadline; still, he appended these three unseen objects as numbers 101, 102, and 103 to the supplement.

After the supplement was printed, Méchain published a letter of correction saying that M102 is "nothing but an error. This nebula is the same as the preceding No. 101. In the list of my nebulous stars communicated to him M. Messier was confused due to an error in the sky-chart."

What's more, two positions of M101 do exist. The 1781 position of M101 places it 1¾° to the west of its modern position. It also places M101 a mere 40 arcminutes from the 6th-magnitude star 86 Ursae Majoris. This, of course, would explain why Messier, in his description of what he thought was M102, writes, "Close to it is a sixth-magnitude star."

On the other hand, the 1781 position of M101, when converted to modern coordinates, differs from the one in the NASA Extragalactic Database by a mere one arcminute. This could be the position of M101 published in Messier's catalog to which Méchain referred.

Despite Méchain's letter and that the above research provides a viable solution to the mystery, others believe that Méchain's observation of M102 best describes spiral galaxy NGC 5866.

On the SEDS website (http://messier.seds.org/m/m102d.html), Hartmut Frommert presents an equally intriguing argument for NGC 5866 to be M102. The full article and a supplement are well worth reading, and I encourage you to do so.

Stephen James O'Meara
Contributing Editor

Send us your questions

Send your astronomy questions via email to **askastro@astronomy.com**, or write to Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

10 Classic telescopes remembered

Some of our best memories of celestial sights have come through telescopes we wouldn't even look at *today.* **by Glenn Chaple**

The author poses with four of his classic telescopes. The smallest overall is the red Edmund Astroscan. The largest is the blue Coulter Odyssey 13.1-inch reflector. The Edmund 3-inch reflector sits in the foreground, and the author's left hand rests on his 2.4-inch Tasco 7TE refractor. GLENN CHAPLE

Fanciers of classic American cars *ooh* and *aah* at the sight of a pristine 1955 Ford Thunderbird, '57 Chevrolet Bel Air, or '70 Dodge Challenger. They get giddy whenever they encounter a 1959 Cadillac Coupe Deville or '64 Ford Mustang convertible on the highway.

Astronomy aficionados experience the same sense of awe and reverence in the presence of a late-19th-century Alvin Clark refractor. With its elegant appearance and exquisite workmanship, a Clark refractor is to an amateur astronomer what an early-20th-century Rolls-Royce Silver Ghost is to an automobile enthusiast.

Glenn Chaple — *a lover and user of classic telescopes — is a contributing editor of* Astronomy *who authors the "Observing Basics" column each month.*

The October 4, 1957, launch of Sputnik 1 ushered in the Space Age and a surge in interest in astronomy and space science. Enterprising companies responded by manufacturing and marketing telescopes designed for the general public. Several of these, due to their widespread popularity, innovative design, or superb optical and mechanical quality, became favorites. Many are still in use today — classic telescopes that collectors and amateur astronomers who prefer something more traditional than a modern-day go-to scope still seek. Here are some notable telescopes I remember from my lifetime of observing.

A. C. Gilbert

❶ 80-power Reflecting Telescope

The A. C. Gilbert Company was a toy manufacturer that specialized in science-related kits, primarily erector and chemistry sets. On the heels of the Sputnik launch, they began marketing a low-cost 2.5-inch f/12 reflecting telescope. One of these, which I borrowed from a high school friend, got me started in astronomy.

By modern standards, it was a "junk" telescope with a rickety mount, a finder scope composed of a soda-straw-like metal sighting tube, and a narrow-field 80x Ramsden eyepiece. Despite the deficiencies, the thing worked, taking me on my earliest cosmic voyages. In its heyday, a Gilbert reflecting telescope with rectangular zippered carrying case retailed for about $20. You still can find some on eBay being offered for two or three times that amount.

Edmund Scientific

❷ Space Conqueror

A contemporary of the Gilbert reflector was the Space Conqueror, Edmund Scientific's 3-inch f/10 reflecting telescope. In 1966, I purchased one from a friend for $15 — half its catalog price. The Space Conqueror was a logical upgrade from the Gilbert scope because it had a sturdier mount, a tad more aperture, a 3x finder scope, and a more practical 60x eyepiece.

It was still a bare-bones scope (the oclar was a 0.965-inch-diameter Ramsden microscope eyepiece, and the tube was made of Kraftboard — a forerunner of Sonotube), but it performed admirably. For 14 years, this little scope was my primary space vehicle, capturing a remarkable array of celestial sights from the Moon to galaxies in the Virgo Cluster 60 million light-years away. I devoted an entire "Observing Basics" column to this scope ("Size Doesn't Have to Matter" in the April 2011 issue).

The A. C. Gilbert Company manufactured this 2.5-inch f/12 reflector, selling it for around $20. Note that the instrument's "finder scope" is simply a long metal tube. STEVEN STEWART

The Unitron 152 is a 4-inch f/15 achromatic refractor was popular from the late 1950s through the early 1980s. A brisk market still exists for these instruments. MICHAEL E. BAKICH

Criterion Manufacturing sold several sizes of reflectors, but none approached the popularity of its RV-6 Dynascope. The tube came with a pier, a motor-driven equatorial mount, two eyepieces, and a finder scope — all for $219.95. ASTRONOMY

California-based Cave Optical manufactured one of the best-selling lines of telescopes throughout the 1960s and early 1970s. It was a beast to transport but gave high-quality views. This ad is from the first issue of *Astronomy*, August 1973. ASTRONOMY

Tasco

❸ 7TE

How often have you watched a movie or television show and noticed a telescope placed beside a window? It can be a major distraction to amateur astronomers because we forget the plot and try to determine the make of telescope. They have one thing in common: All are refractors. The design meets the public perception of what a telescope is supposed to look like — a long tube atop a wooden tripod with an eyepiece at the end opposite the main lens.

The Tasco 7TE series of telescopes, introduced in the late 1950s, exemplifies this traditional design. Unlike the junky 2.4-inch Tascos that began showing up in department stores in the 1960s, the 7TE was a thing of beauty. Early models retailed for around $150 — a hefty price in those days but still a bargain when compared to Unitron refractors. Like Unitrons, the Tasco 7TE and its accessory parts were housed in an attractive wooden box. Worthy as a display piece next to an office or apartment window, the Tasco 7TE 60mm f/15 equatorial refractor looks even better when set up in your backyard.

Unitron

❹ Model 152

We might look at Unitron telescopes as the Clark refractors of the mid-to-late 20th century. They were a definite step up from the Tasco 7TE line, with an equatorially mounted 2.4-inch Unitron running for about half again the cost. A unique feature of the Unitron refractors was the optional rotating eyepiece holder (the Unihex and later the Super Unihex, which held 1¼" eyepieces) that attached to the end of the tube and allowed the switching of eyepieces with a mere twist of the hand.

If I were to pick out a single classic Unitron, however, it would be the 4-inch equatorially mounted Model 152. I first used one of these scopes, which the owner had bought in the late 1950s for nearly $800, at a star party in the early 1970s. The highlight of the session was the incredibly crisp views of double stars that the 152 delivered.

Celestron's C8, an 8-inch Schmidt-Cassegrain telescope that debuted in 1970, shook up the entire amateur astronomy community. The folded optical design created a compact tube that was easy to transport and set up. CELESTRON

Criterion and Cave Optical

❺ Dynascope RV-6

❻ 6-inch Student Model Astrola

It's easy to think of the 1960s as the decade of the 6-inch f/8 reflecting telescope. Two models of this all-purpose design, Criterion's Dynascope RV-6 and Cave Optical's 6-inch Student Model Astrola, were the most sought-after models. Selling

for around $200, both delivered quality optics housed in a white metal tube that was supported by a heavy and sturdy pedestal mount with motorized drive (standard in the RV-6, but optional in the Astrola for an additional $65). These long-tube reflectors remained top sellers until the appearance of the compact Schmidt-Cassegrain design in the early 1970s.

Edmund Scientific

7 Astroscan

It's a red bowling ball. It's a red bowling ball with a red tin can affixed to its side. It's a red bowling ball/tin can assembly nestled into a doggie dish. No, it's an Astroscan! Edmund Scientific's award-winning design hit the market in 1976 and was an immediate success. A rugged little 4.2-inch f/4.2 rich-field scope, it found favor with amateur astronomers looking for a bridge between binoculars and high-power scopes. Its 28mm eyepiece produced a breathtaking 3°-wide field of view. Sadly, this wonderful scope is no longer made (although I hear Edmund currently is working to return the Astroscan to production). In the meantime, an online search can net you a used Astroscan for around $200.

Many amateur astronomers consider the Questar 3.5 Maksutov-Cassegrain catadioptric reflector as the world's finest personal telescope. QUESTAR CORPORATION

Celestron

8 C8

Orange became the new black decades before Piper Kerman's prison memoir and subsequent Netflix series. In 1970, Celestron introduced the C8, the first mass-produced Schmidt-Cassegrain telescope (SCT). An 8-inch f/10 SCT with a distinctive orange tube, the original C8 sold for $795. The scope was an immediate mega-success, offering high-quality optics in a compact package. At star parties, C8s dotted the landscape like pumpkins in a field. Not only was the C8 more portable than the Newtonian reflectors of the 1950s and '60s, but it also was more adaptable to astrophotography. The C8 is still available today. For an in-depth illustrated history of the C8, go to Ed Ting's Telescope Review website at www.scopereviews.com/C8History.html.

Coulter

9 Odyssey I

There's a reason I was a devotee of small-telescope astronomy from the mid-1960s until 1980. I simply couldn't afford a medium-sized scope with its expensive equatorial mount. San Francisco telescope maker John Dobson came to the rescue, and Coulter Optical Company tossed me a lifeline when it introduced the Odyssey I — the world's first commercially made Dobsonian-mounted Newtonian reflector. Anyone now could purchase a — what then seemed massive — 13.1-inch f/4.5 reflecting telescope for the eye-opening cost of just $395. True, the optics weren't as sharp as those of the 6- to 8-inch equatorially mounted Newtonians being sold at the time (I overcame this deficiency by using an aperture mask), but this "light bucket" could reel in faint deep-sky objects I'd previously only been able to read about. The original Odyssey I was of primitive design. The optical tube assembly was housed in a box-like structure that rested on the base. Later Odyssey I scopes (and Dobs produced by competing companies) eliminated the box and set the tube directly on the base.

Questar

10 3.5

We finish with the Cadillac of classic telescopes, the Questar 3.5-inch Maksutov-Cassegrain. It entered production in 1952 and found favor with serious amateurs. Its exceptional optical quality came at a price, however. Back then, a Questar 3.5 sold for around $800. A testament to its success is the fact that it's still in production more than 60 years later.

Naturally, the price has risen. A Questar 3.5 package currently costs about $4,600. Even original Questars appear on the used market for several thousand dollars. Is the price worth it? I think so. This little scope produces image sharpness that defies belief, and the craftsmanship is akin to the finest Swiss watch.

Is a classic for you?

Fanciers of classic telescopes will want to research the above scopes on the Internet. If you're an astronomical old-timer who remembers the "days when," you'll want to look into Phil Harrington's collection of vintage telescope ads (www.philharrington.net/old.htm) and Robert Provin's collection of catalogs and manuals (http://geogdata.csun.edu/~voltaire/classics/).

Which of today's crop of commercially made telescopes will be the classics of tomorrow? Come back in three or four decades, and we'll have another look!

Around the world in eight star parties

From Switzerland to South Africa, these star parties all promise dark skies, good telescopes, and great company.

by Tom Trusock

Everybody loves a party, and astronomers around the world are no exception.

British monarch King George III allegedly held the first star parties in the 18th century. Primarily designed to show off his scientific instruments and intelligence, they still made for a good time. Today, many observers will back out of a star party if the weather looks unfavorable. In George's day, if the skies were cloudy, servants were said to have simply hung paper targets around the courtyard for guests to view.

While modern star parties lack servants, organizers still try to keep the atmosphere festive in their own

Astronomers from around the globe love a good star party. Here are eight of the best. NASA GODDARD SPACE FLIGHT CENTER/RETO STÖCKLI/ROBERT SIMMO/MODIS/USGS

way. Amateurs today enjoy attending star parties for lots of reasons, but prime among them are trying new gear, experiencing dark skies, and meeting friends new and old.

American amateur astronomers are lucky. We have a lot of fantastic star parties right in our own backyards. But there's so much more the world has to offer, for those venturing farther afield. Ever dream about viewing the stars from Africa or the Alps? How about partying with 20,000 new friends in Japan? What about viewing the far southern skies through a monster (30-inch) telescope?

Worldwide, one fact holds true: If there are amateur astronomers, there will be star parties. Let's look at some opportunities near to home and very far away.

Tom Trusock *is a veteran observer who lives in Ubly, Michigan.*

MALCOM PARK (1); LACHLAN MACDONALD (2); TAINAI STAR PARTY (3); GREG PRIESTLEY (4); MANUEL JUNG (5); TANJA SCHMITZ (6); DAVE EAGLE (7); PHILLIP EASTON (8)

1 CANADA Starfest

MALCOM PARK

Bring your tent and your family when you come to Starfest, and you'll be in good company.

Who: North York Astronomical Association
Website: www.nyaa.ca
Where: River Place Park, Ayton, Ontario
When: August, one long weekend
Astronomy vendors: Yes
Prices and lodging: The registration fee is $60 (CDN) for individuals or $90 for families (and $10 more if you book last minute). Starfest is held at a private campground, so be aware that there is an additional fee for camping and entrance to the park. Enjoy the flush toilets and coin-operated showers on site.

Starfest is one of Canada's best known and largest star parties, with past attendance peaking at over 1,000 individuals. It offers good skies and a family-friendly environment, with plenty of activities for the youngest astronomers in your group. Make your reservations early because it fills up quickly. In addition to the campgrounds, there are a number of relatively nearby motels or bed-and-breakfast selections at varying prices. Daytime events involve relaxing with friends and taking in a variety of speakers — I had the honor of presenting this past year.

2 AUSTRALIA OzSky Star Safari

Who: Three Rivers Foundation (3RF) Australia
Website: www.ozsky.org
Where: Coonabarabran, New South Wales
When: April, one week
Astronomy vendors: No
Prices and lodging: OzSky costs $525 (AUD) for registration and $350 for accommodations. On-site lodging is available at the Warrumbungles Mountain Motel right next to the observing field, with additional off-site lodging located a few miles away.

Limited to 36 observers, this is more star safari than traditional star party. Foreign observers who've come to observe the southern celestial sphere are the target audience, and observing is the priority. Telescopes from 12 to 30 inches are available on site along with guides who know the southern sky like the back of their hand. If you wish to be more of an operator than a tourist, they offer training sessions on their telescopes, and if you wish to go whole hog and bring your own gear, you're more than welcome. Electricity is available on the observing field, but have no fear about white lights here. Dark skies are the rule, and the entire complex is geared toward astronomy for the week.

LACHLAN MACDONALD

Enjoy some truly great gear at OzSky, including telescopes up to 30 inches in diameter provided by the organizers for shared use.

3 JAPAN Tainai Star Party

Dark skies are in short supply at the Tainai Star Party, but the festive and friendly atmosphere makes it all worthwhile. TAINAI STAR PARTY

Who: Tainai City and the Japan Planetarium Lab
Website: www.tainai.jp
Where: Tainai City, Niigata Prefecture
When: August, one weekend
Astronomy vendors: Yes
Prices and lodging: There is no registration fee. The Royal Tainai Park Hotel is both close and convenient, and other lodging is available in nearby cities. Camping is available at outlying locations for those attempting to do more serious observing or photography.

Now going on 32 years, this is quite possibly the world's largest gathering of amateur astronomers. Unlike most of the others on this list, the Tainai Star Party places the emphasis on *party*. Thousands of people (past attendance has surpassed 20,000), daily concerts, and adult refreshments only add to the fun. Let's be clear: Observing is not the real draw. Don't be surprised to see white lights, strobes, and even fireworks. But the gorgeous location, fun-filled atmosphere, and myriad vendors make up for it.

4 AUSTRALIA South Pacific Star Party

Who: Astronomical Society of New South Wales
Website: www.asnsw.com/node/712
Where: Wiruna, near Ilford, New South Wales
When: May, one long weekend
Astronomy vendors: Yes
Prices and lodging: Registration is $75 (AUD) per individual, or $105 per family. There is an additional $10 surcharge for registering at the gate. Camping is the preferred choice for most observers, with both tents and RVs allowed. Firewood, barbecues, hot showers, and flush toilets are available, with additional off-site accommodations only a short drive away.

The South Pacific Star Party is a bit different from most observing gatherings in that the 100 acres of land here are owned by the club and thus dedicated to stargazing. Near Wollemi National Park (the largest declared wilderness area in New South Wales), the skies are exceptionally dark, making for top-rate observing.

Spend the daylight hours visiting nearby gold mining towns or the many local wineries, or engage in some birdwatching. And if you just can't wait for nightfall to bring more astronomy to your trip, be sure to take in a visit to the Anglo-Australian Observatory at Siding Spring three hours north of Ilford.

The Milky Way's graceful sprawl is only one reason to travel south in search of spectacular skies. GREG PRIESTLEY

5 SWITZERLAND Swiss Star Party

While nighttime observing is obviously the goal, the stunning landscapes during the daylight hours at the Swiss Star Party won't disappoint. MANUEL JUNG

Who: Swiss Amateur Astronomers
Website: www.teleskoptreffen.ch/starparty
Where: Gurnigel Pass in the Bernese Alps outside Bern
When: August, one weekend
Astronomy vendors: No
Prices and lodging: There is no registration, site, or camping fee; however, the location is probably not the best for camping. Recommended accommodations can be found instead at the Berghaus Gurnigel Mountain Lodge and run the gamut from a military-style dormitory (bring earplugs!) to single or double rooms.

This is probably the only star party ever offered on a tank firing range, so you're going to be in for a unique experience. With skies featuring a naked-eye limiting magnitude of 6.5 to 7.0 (although with a slightly truncated view due to mountains toward the south), this is a quintessential observers' star party. Unlike most of the other star parties on this list, there are few, if any, organized events. If you enjoy the outdoors, you won't lack for things to see and do during the daytime. The local scenery is absolutely stunning.

6 SOUTH AFRICA Mountain Sanctuary Park Star Party

Who: West Rand Astronomy Club
Website: www.wrac.org.za/events/wrac-annual-star-party-at-mountain-sanctuary-park
Where: Mountain Sanctuary Park, Magaliesberg
When: August, one weekend
Astronomy vendors: No
Pricing and lodging: Attendance is free. Log cabins, chalets, and huts are all available. If you'd rather sleep under the stars, there's always the camping option as well.

With over 170 attendees in 2014, the Mountain Sanctuary Park Star Party is one of the Southern Hemisphere's largest gatherings. In direct contrast to the Tainai Star Party, the emphasis on this private nature reserve in the Magaliesberg Mountains northwest of Johannesburg is on its quiet, stress-free location. The phrase, "If you can't relax here, you need medical attention," is prominently featured on its website.

At night, you'll find a dark celestial sphere open to you. During the day, mountain bikers, hikers, swimmers, and rock climbers will find plenty to do. If you'd rather indulge in a serene bit of nature watching, there is a variety of South African wildlife found on the reserve.

You won't have any problem with crowds in the Mountain Sanctuary Park. Come prepared to kick back and relax with your fellow stargazers. TANJA SCHMITZ

7 UNITED KINGDOM Equinox Sky Camp

Who: Loughton Astronomical Society and the Kelling Heath management
Website: www.starparty.las-astro.org.uk
Where: Kelling Heath Resort, Norfolk
When: September, one weekend (but there is an extended camp that runs for 11 days surrounding the main event)
Astronomy vendors: Yes
Prices and lodging: There is no registration fee. Kelling Heath has several different accommodations; lodges, holiday homes, and campsites are available for various prices beginning around £21, with reduced rates for star party attendees.

The star party at Kelling Heath is in a prime remote location and boasts some of the best skies in the UK. In addition to the usual astronomy talks and vendors, daytime activities include tennis, hiking, and swimming, either on the resort property or in one of the nearby attractions. Blakeney and Holkham National Nature Reserves, the River Glaven, and the North Norfolk Heritage Coast are all nearby.

The UK is not known for its clear skies, but Kelling Heath proves that starwatching there can still be a memorable experience. DAVE EAGLE

8 UNITED STATES Okie-Tex Star Party

DANNY MACDONALD

The star party's two flamingo mascots, Okie and Tex, keep a careful eye on the camp from above.

Who: Oklahoma City Astronomy Club
Website: www.okie-tex.com
Where: Camp Billy Joe, outside Kenton, Oklahoma
When: September, one week
Astronomy vendors: Yes
Pricing and lodging: Registration is $50 per person, with an additional $5 per day facility fee. There are six insulated and heated bunkhouses. Tent campers, trailers, or RVs are also welcome, but be aware there are no hookups available. If you're not a fan of dry camping, you can find hookups at the nearby Black Mesa State Park. For those who like a few more amenities, there is alternate local lodging.

Wrapping up the list is one of my absolute favorite star parties, right back here in the States (since we're also part of the world).

Okie-Tex is the only star party I know of that lists their latitude and longitude in lieu of directions. Getting to this shindig, located in the Oklahoma Panhandle, is really half the fun. To arrive by air, you probably want to fly into Amarillo, rent a car, and then drive north for three hours. It's not the easiest place to reach, but the payoff is prime stargazing under one of the best skies in North America, with fellow hobbyists just as dedicated and excited to share the stars.

Just down the road from Camp Billy Joe, you'll find Black Mesa State Park, home to such wildlife as mountain lions and black bears. Other "local" attractions include dinosaur quarries and the Capulin Volcano. For those who love the wide-open outdoors, this is one of the United States' most awe-inspiring areas.

TURNING ON TO THE STARS AGAIN

Kids aren't the only ones who can benefit from astronomy education.

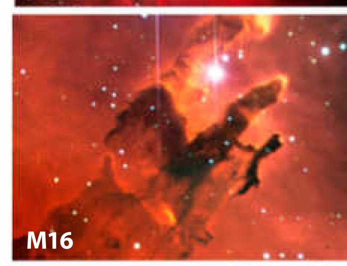
by Amy Tyndall

If the weather is warm and the sky is clear, adult astronomy education can take place under the stars. This session, held in August 2013 at Lake Tahoe, California, taught attendees about meteor showers, particularly the Perseids. RYAN BERENDSEN

> By exciting children and teenagers with images and stories of the cosmos, we hope to inspire them to bring their passion and talent to a career in astronomy later in life.

Magazines, books, planetarium shows, museum exhibits, and trips to industry can all help in this task. For some children, it works; they go home captivated by what they have seen. They read about it, talk about it, and keep a part of their newfound love for the subject with them throughout their life.

It is apparent, however, that such astronomy outreach is rarely aimed directly and solely at adults, to the older generations who have already made their major life decisions. But why should we be teaching astronomy only to the young? Is it somehow less important for adults to hear about, and be inspired by, what lies beyond the confines of our atmosphere?



Adult students enrolled in the distance learning program at the Astrophysics Research Institute at Liverpool John Moores University in England took these images as part of their courses. THE LIVERPOOL TELESCOPE, LIVERPOOL JOHN MOORES UNIVERSITY

Advanced learning

"Anybody who wants to learn should be able to, and anything we can do to make that happen is important," says Andy Newsam, professor of astronomy education and engagement at the Astrophysics Research Institute (ARI) at Liverpool John Moores University in England.

"Astronomy is something that appeals to almost everyone, regardless of age, social background, ethnicity, or gender," he says. "As such, it is an ideal way of increasing people's interest in science as a whole — and indeed in all STEM [science, technology, engineering, and mathematics] subjects."

Newsam is also program leader for the astronomy distance learning courses offered by the ARI. Such courses target adults who would like a more formal academic introduction to the subject yet require it to fit around their weekly schedule. Enthusiasts of any age, background, and location may earn a certificate in topics such as "Supernovae" or "The Science of the Night Sky." Seeing how the 200 or so mature students who sign up every year throw themselves into learning means

Michael Faison shows astronomy devotees an image of dark nebula Barnard 68 at BAR in New Haven, Connecticut. Faison participated in the Astronomy on Tap program. FABIO DEL SORDO

that Newsam understands very well the need to go beyond the school walls.

"While there is an obvious direct benefit for young people who may then go on to choose STEM careers, to ignore the rest of the population would be a very big mistake," he says. "Even if you only consider influencing young people to be important, probably the biggest influence on them is their family and relatives. So, if we get an aunt or grandparent interested in science, that may have important knock-on effects."

Tapping into a need

Megan Schwamb, currently a postdoctoral fellow at the Academia Sinica Institute of Astronomy & Astrophysics in Taipei, Taiwan, believes that engaging students is important for more than just influencing what subjects they go on to study. "I think outreach humanizes scientists, creating realistic role models and breaking people's perceptions from Hollywood and cultural stereotypes, so that young people can see what it's like to be an astronomer and realize that they can be one, too," she says.

Schwamb also has noticed a gap in the market for astronomy outreach and has gone to great lengths to create something more adult friendly. She co-founded a free monthly outreach event named Astronomy on Tap while on a postdoctoral fellowship at Yale University in Connecticut.

Astronomy on Tap offers a mature audience the chance to listen to accessible and fun presentations — just 10 minutes long — given by local astronomers on a wide range of topics from exoplanets to the physics behind the movies. Organizers intersperse these talks with fun games and the chance to win prizes — all over a pint of beer in a local bar.

"I started Astronomy on Tap originally because I had been interacting a lot with the public through blogging, Twitter, and streamed live chats, but I think there is something different about the Internet," she explains. "It has incredible power and global reach, but it lacks the closeness I think you get from directly interacting with people face-to-face.

"So I also wanted to get involved in some way talking to people in person about what I and my colleagues do as planetary scientists and astronomers."

Although Schwamb is aware that the idea of informal public talks is not new, what she feels makes Astronomy on Tap stand out from the rest is the eclectic mix of information that the attendees receive, summarizing the current goings-on in astronomy and space science. By keeping it informal and maximizing participation, it opens up a more relaxed dialogue between the professionals and the public.

She originally named it Astronomy Uncorked due to its location in a local wine bar, but increasing interest meant that she needed to expand. "I realized that to get it really going, a bigger city would be better, so I started looking for venues in New York City," Schwamb says.

"The idea of integrating games and other features as well as the renaming to Astronomy on Tap came from Emily Rice,

The Astronomy on Tap program provides easy-to-digest snippets of some facet of astronomical knowledge to adult students. Each talk — like this one that took place at the Science Club in Washington, D.C. — lasts no more than 10 minutes. JACKIE FAHERTY

Amy Tyndall *obtained her Ph.D. in astrophysics from the University of Manchester, England, and is a freelance science writer.*

an astronomer at the College of Staten Island/CUNY and the American Museum of Natural History, who's done a fabulous job continuing on the New York City branch after I moved to Taiwan."

The vision of these women has resulted in a global spread of Astronomy on Tap, with regular monthly slots now being held in Columbus, Ohio; Austin, Texas; Toronto, Canada; and Santiago, Chile (which I currently organize), resulting in astronomy reaching thousands of adults across dozens of events.

Science for seniors

However, a person doesn't always have to go out in search of astronomy events. In some circumstances, astronomy can come directly to the people. The outreach work of Valerie Rapson, a doctoral student at the Rochester Institute of Technology in New York, is proof that curiosity does not fade away with increasing age and that we should continue to nurture it.

"Back in 2010, I was invited to a local senior living community to give a short talk about my research as part of their Lifelong Learning program," Rapson says. "The community liked it so much that they invited me back to discuss my favorite astronomy topics. It was then that I learned that many senior living communities have educational programs — they mostly focus on history, cooking, exercise, etc. — but that science lessons are few and far between. I now actively give astronomy lessons at five different communities."

During her time with the residents, Rapson has spotted an obvious generational issue that is often overlooked. "Many seniors — especially the women — did not have a chance to go to college, or if they did, they didn't have a chance to study astronomy," she explains. "My lessons tend to bring roughly a 50/50 ratio of men and women, and often the women come up to me afterward and say that they find the material fascinating and would never have had the opportunity to learn about it on their own."

Return on investment

Although the desire to share their passion with the wider world is the main driving force, it's not the only reason why professional astronomers become proactive with public engagement. What Newsam, Schwamb, and Rapson agree on is how closely tied to politics astronomy is, and politically driven budgets end up being their main source of funding. For them, this makes outreach an even more vital part of their job.

"If we want to live in a world where funding for science is more abundant, then we need to convince the general public that it is worth their time and money to invest in scientific pursuits," Rapson says.

"Hopefully this will lead to the election of politicians who are willing to put money back into NASA and other endeavors."

"I think it's really important not just for institutions and departments to carry out outreach, but for scientists themselves to directly engage with the public in one form or another," emphasizes Schwamb. "Most of science funding comes from government grants and thus directly from people's tax money. The general public is a part of the story, and we as scientists should bring them along for the rest of the journey."

"THE GENERAL PUBLIC IS A PART OF THE STORY, AND WE AS SCIENTISTS SHOULD BRING THEM ALONG FOR THE REST OF THE JOURNEY."

— Megan Schwamb

With such eager, committed astronomers like these taking the initiative, it would be impossible not to have some of their energy rub off on the people they interact with. However, the beautiful thing is that no matter how much knowledge someone can impart, chances are they will come away having learned something valuable themselves — all they need do is listen. This symbiotic relationship between the professional and the public is what will continue to drive the science forward.

"The best part for me is talking to the seniors afterwards and hearing what they have to tell me," Rapson says. "I have met so many people who worked on the Hubble backup mirror as Kodak employees in Rochester, or have children or grandchildren who work for NASA, or who are actively involved in astronomy in some way. It's amazing to hear these stories firsthand from people who lived through some of astronomy's best years. Often, people will bring in newspaper clippings or even old articles from *Astronomy* and say, 'I was a part of this!'"

Adults who may never have looked at the magnified image of a celestial object genuinely enjoy their first close-up views of the Moon, Saturn, and double stars. VALERIE RAPSON

As a speaker in the Astronomy on Tap program, Ivelina Momcheva gives the crowd at BAR in New Haven, Connecticut, an entertaining 10-minute talk on astronomy. FABIO DEL SORDO

Help tell the story

Indeed, the nature of our universe is perhaps the most important and captivating story of all, and one that every generation deserves to hear. Rapson says that she welcomes ideas from readers or others who would like to get involved in astronomy outreach for senior citizens, either in Rochester or in their own area. If you want to learn more, please contact Rapson at vrapson@gmail.com.

It doesn't necessarily have to be professional astronomers conducting this outreach — amateur astronomy clubs, school astronomy clubs, or anyone with knowledge in the subject can be a part. The main point is to get involved — at whatever level — to help make learning about astronomy something that anyone can pursue no matter their age.

We test Starlight Xpress' new camera

Light weight, low noise, and high quantum efficiency make the Trius-SX694 CCD camera a winner. **by Tony Hallas**

The Starlight Xpress Trius-SX694 CCD camera measures less than 3 inches (76 millimeters) on a side and weighs only 14.1 ounces (400 grams). COURTESY STARLIGHT XPRESS

If you know me, you know I'm all about performance in a CCD camera. Recently, however, I discovered that good things can come in small packages. Starlight Xpress always has designed its CCD cameras around a compact architecture, and the company's latest entry, the Trius-SX694, is no exception.

The camera contains a third-generation Sony EXview Progressive Scan CCD chip with high quantum efficiency and extremely low thermal noise. The CCD chip features a matrix of 2,750 by 2,200 4.5-micron pixels in an active area measuring 12.5 by 10.0 millimeters. Some quick math and you will see that this is the ideal aspect ratio: It scales up to 8-by-10 or 16-by-20 print sizes without any waste.

Lots of details

The quantum efficiency (QE), or the percentage of photons the chip records, peaks at 77 percent in yellow light, with an excellent 65 percent from blue all the way to Hydrogen-alpha wavelengths. Beside the excellent QE, the broad spectral response works well with Astrodon series E filters, giving a combined ratio under dark skies close to 1:1:1.

All this means is that you can take and stack equal exposures for your final result. The anti-blooming (which restricts light to the pixels on which it falls) is superb, so you lose no active area despite the small size of the pixels.

The optional off-axis guider includes a pick-off mirror that captures light through the same optics the CCD camera uses. TONY HALLAS

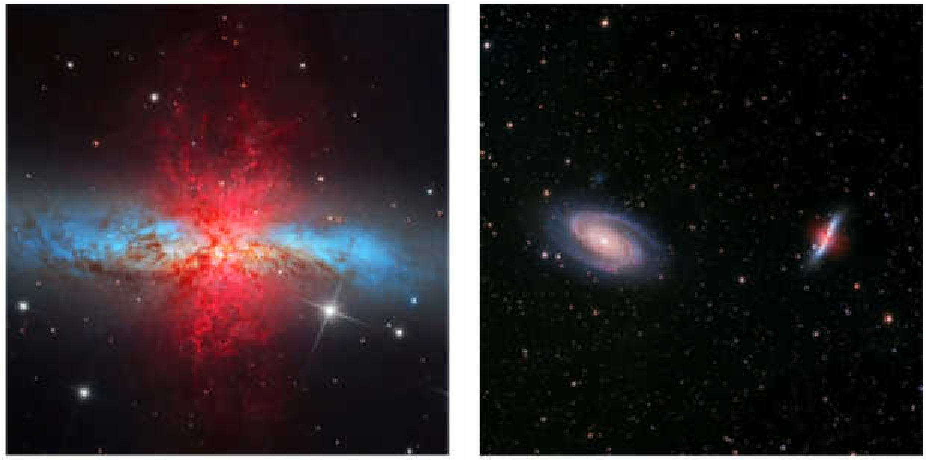
If I were to characterize this CCD camera, "versatile" is what comes to mind. I have used it with my 14.5-inch f/8 Ritchey-Chrétien scope at a 3,000-millimeter focal length for close-up views of celestial objects. And I've used it on my 4-inch f/3.8 astrographic refractor, which has a 380mm focal length, for wide-field views. Conventional wisdom dictates that the recorded detail is grossly oversampled (in other words, too many pixels per unit area) at 3,000mm, but I have found that this is not the case. Oversampling an image allows for better deconvolution (which lets you create sharper images), and it lets you reduce the sizes of stars because the image-processing software has finer increments to work with.

You do pay a slight price for such small pixels, and that is the deep-well capacity — how much light a pixel can hold before it saturates (fills up and is no longer effective). The deep well for each of the SX694 chip's pixels is approximately 20,000 photons, but it really doesn't matter in practice. If you have an image with a bright area, you'll want to shoot some shorter exposures and blend them with longer ones to pull out the fainter areas. This procedure is

Tony Hallas *is a California-based contributing editor of* Astronomy *and one of the world's preeminent astroimagers.*

PRODUCT INFORMATION

Starlight Xpress Trius-SX694
Type: CCD camera
Chip: ICX694AL EXview CCD
Quantum efficiency: 77 percent (yellow light); 65 percent (Hydrogen-alpha)
Power consumption: Less than 1.5 amps at 12 volts DC
Dimensions: 2.95 by 2.76 inches (75 by 70 millimeters)
Weight: 14.1 ounces (400 grams)
Price: $2,795
Contact: Starlight Xpress
Unit 3, Brooklands Farm
Bottle Lane
Binfield, Berkshire
RG42 5QX
United Kingdom
[t] +44 (0) 118.402.6898
[w] www.sxccd.com



This pair of images illustrates the versatility of the Trius-SX694. The author took the close-up image of the Cigar Galaxy (M82, left) through his 14.5-inch f/8 Ritchey-Chrétien reflector, which sports a 3,000-millimeter focal length. He captured the wide-field image of M82 and its companion, Bode's Galaxy (M81), through his 4-inch f/3.8 astrographic refractor (380mm focal length). TONY HALLAS

standard when imaging the Orion Nebula (M42), for example.

I can illustrate the versatility of the Trius-SX694 by letting you compare the two images of M82 that you'll find to the upper right on this page. I took the left with my 14.5-inch scope and the right with my 4-inch refractor. The 4.5-micron pixels worked extremely well with both telescopes due to the low noise, high overall QE, and excellent spectral response.

New features

The Trius is the latest camera body design from Starlight Xpress, and it has some new features. The company filled the CCD chamber with dry argon to improve the cooling. That coupled with a high-performance, two-stage cooler can bring the chip's temperature to 72° F (40° C) below ambient. On the back, you'll find a three-port powered USB hub that can drive a Lodestar guider and the SX filter wheel. All you need is a single USB connection to the computer.

All Trius cameras use a multicoated fused-silica window at the front of the camera to seal the CCD chamber. Using this material ensures that all the near-ultraviolet and infrared light entering the camera can do so unhindered, letting you capture a greater spectral range. It also has better heat transfer characteristics than glass, so as the camera body warms, the front window also warms slightly to help prevent dew from forming.

I have used many CCD cameras in my life, but none allowed me to get to the filters as easily as the SX filter wheel. You simply unscrew a few thumbscrews, remove the back, and there they are. It's so easy to clean the filters that you could do this before every image if you wanted to.

You also can attach the company's accessory off-axis guider directly to the filter wheel, which makes for a compact imaging system. The guider features an easily adjustable prism height to let you decide how much of the light beam to capture before the prism casts a shadow on the CCD. A little experimentation will give you the perfect setting. Many other interface options allow you to attach the front of the filter wheel to just about anything.

Because of its compact size and efficient design, the Trius-SX694 weighs only 14.1 ounces (400 grams). Users of heavy CCD cameras will be surprised when they pick up this camera and its filter wheel. The light weight greatly reduces the possibility of focuser sag.

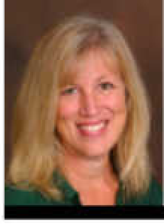
The optional filter wheel (shown here with filters removed) uses the same power as the Trius-SX694. Its positioning system also returns absolute filter locations, so you won't lose the filter wheel's position. TONY HALLAS

Because the SX694 lacks a mechanical shutter, you will need to cover the camera to shoot dark frames. Initially this seemed like a lot of extra work, but after I built a library of dark frames, it was inconsequential. (Indeed, the camera has such low thermal noise that you almost can get by without darks if you dither and combine your images with outlier rejection.)

I currently have two Trius-SX694 CCD cameras. One is permanently installed on my 14.5-inch scope, and I can use it either at the f/8 focal ratio (3,000mm focal length) or with a 0.75x telecompressor that reduces the focal ratio to f/6 (2,250mm focal length) for a faster, slightly wider field of view. The other is my portable camera that goes on a variety of telescopes I use either at home or at my super-dark site.

Remember one word

As I said earlier, "versatile." No other word describes the Trius-SX694 as well. At home on almost any telescope, I have found this cameras to be a workhorse with wonderful color capture, extremely low noise, high quantum efficiency, and excellent anti-blooming. Because of the SX694's high-resolution 4.5-micron pixels, small high-quality refractors can produce beautiful, highly detailed results. And, as many of my images show, large telescopes also benefit. Is it the perfect little CCD camera? It comes very close.



ASTROSKETCHING

BY ERIKA RIX

Solar prominences

Just like clouds on a calm day, solar prominences appear almost motionless. Attempt to draw them, however, and you'll discover that both evolve at such a rate that you struggle to keep up. But with a few pointers and following this simple technique, you will soon capture these fascinating structures in record time.

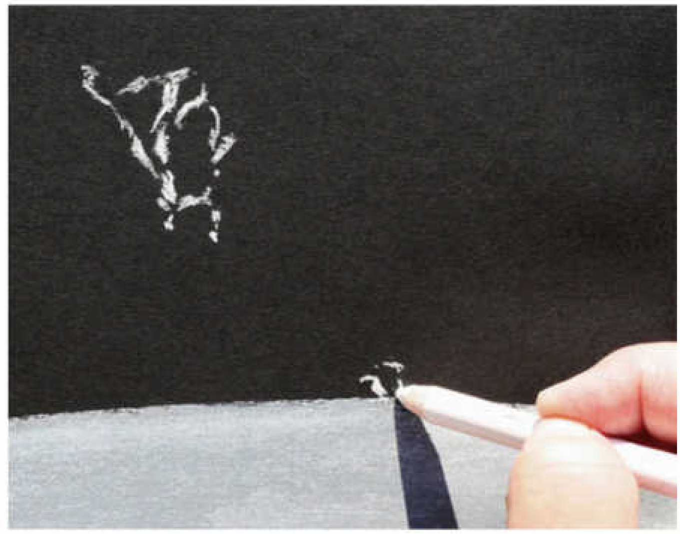
Prominences are regions of relatively cool, high-density gas that lie above the Sun's surface. Observing them requires a narrowband solar filter centered on the Hydrogen-alpha (Hα) spectral line, a specific color of red. If you want to spot the faintest details, you need to escape the Sun's brightest glare. I use both a black solar cloth and a flat shield to block out any light except what's coming through the eyepiece, causing me to look like an old-time photographer.

The sketch media is both basic and effective. All in white, it consists of a pastel stick, a pastel pencil, and a colored pencil. I use black acid-free paper to represent the dark backdrop of the eyepiece view, which has the added benefit of reducing glare when I make additions to the sketch.

Prepare the limb, the part of the Sun's edge with the prominence, by drawing a shallow 5-inch arc on the paper with the flat edge of the pastel stick. Next, fill in the area, and then blend with your fingertips. When the limb is complete, study the prominence through your eyepiece until faint wispy details become visible.

I use the pastel pencil to draw the brightest strands of the prominence first. Look closely at their shapes and relative positions as you sketch, and make sure you draw them to scale with the limb.

A colored pencil has a harder lead that produces faint, slender markings. It works well for detailing, so use that next to add the gauzy wisps within the brighter pastel markings. The harsh pastel will soften as you draw new additions through them. Alternate between the two pencils until the prominence is complete. Because a prominence's shape can change so quickly, strive to complete your sketch in 10 minutes or less.

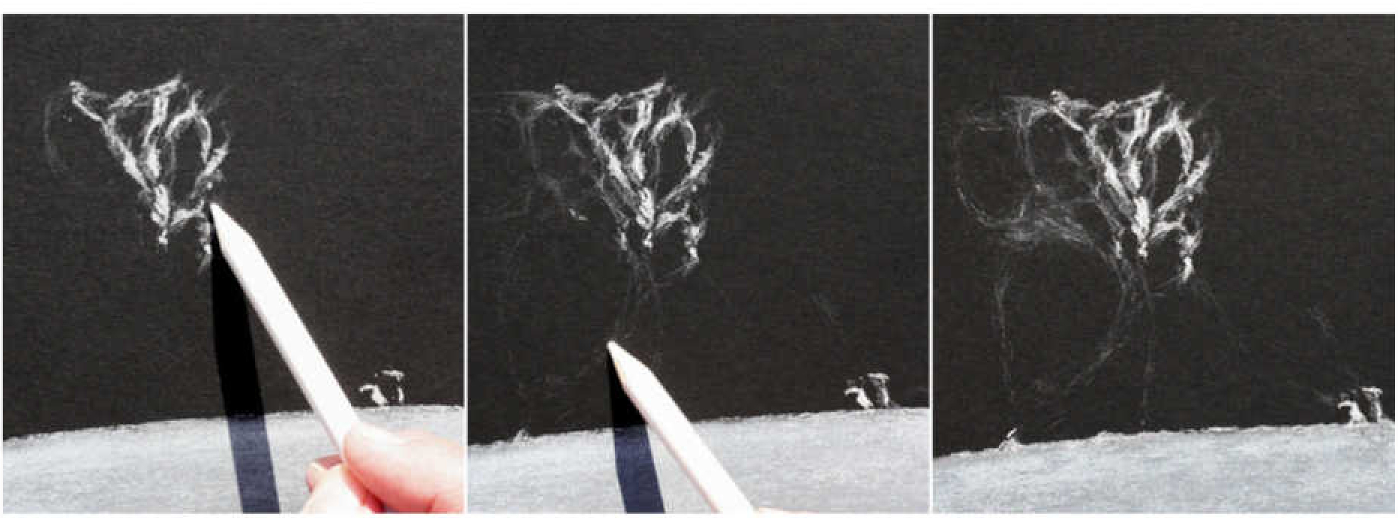


ALL SKETCHES: ERIKA RIX

The author drew the shallow arc of the Sun's limb first and then added the brightest sections of the prominence with a pastel pencil. They functioned as marker points for the remainder of the sketch. She captured this event May 17, 2012, through a 2.4-inch Hydrogen-alpha telescope with a 400mm focal length and 8mm eyepiece for a magnification of 50x. For the sketch, the author used a white Conté crayon and pastel pencil, a white Prang colored pencil, and black Strathmore Artagain paper.

I like to create a series of drawings to capture the changing shape of a prominence over an extended period of time. The one shown below started off a third of its size before breaking free, over five hours later, from the magnetic field that supported it. See an animation of the full eight-sketch sequence at www.Astronomy.com/Rix.

As always, feel free to share comments or questions with me at erikarix1@gmail.com. Clear skies!



The author used a white colored pencil to render faint strands within the large plume before it changed shape (left). Working quickly, she completed the remainder of the prominence by drawing the threads that connected to the limb (center). The author raced time to finish with an accurate and lovely solar prominence (right)!

NEW PRODUCTS

Attention, manufacturers: To submit a product for this page, email **mbakich@astronomy.com**.

Focuser

Starlight Instruments
Columbia City, Indiana

Starlight Instruments' FTF3515-TAK FSQ-106ED Feather Touch 3.5" Diameter Dual Speed Focuser Kit replaces the focuser on Takahashi's refractor. It offers a 10:1 focus speed reduction and a threaded drawtube that accepts Takahashi accessories.

Price: $995
[t] 260.244.0020
[w] www.starlightinstruments.com

Autoguider

Orion Telescopes & Binoculars
Watsonville, California

Orion designed its Mini Deluxe Pro AutoGuider Package for use with telescopes having up to a 1,500-millimeter focal length. The product includes a 2-inch guide scope, finder base, StarShoot AutoGuider Pro CCD camera, and 1¼" nosepiece.

Price: $519.99
[t] 800.447.1001
[w] www.telescope.com

Solar glasses

Rainbow Symphony
Reseda, California

Rainbow Symphony's Wrap Around Eclipse Glasses have high-quality optics that protect your eyes. The glasses reduce the Sun's light to a manageable level and eliminate all infrared and ultraviolet radiation.

Price: $19.95
[t] 800.821.5122
[w] www.rainbowsymphony.com

7mm eyepiece

Tele Vue Optics
Chester, New York

Tele Vue's DeLite eyepiece line is a smaller and more economical version of the company's Delos line. The EDE-07.0 offers a 62° apparent field of view, 20 millimeters of eye relief, and sliding locking eyeguards. The eyepiece weighs 7.3 ounces (207 grams).

Price: $250
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[w] www.televue.com

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COSMIC**IMAGING**

BY ADAM BLOCK

When light strays, part 1

The feeble photons we collect with telescopes and then record with cameras are easily overwhelmed by other photons that find their way into our exclusive astrophotographic party. For the best pictures, imagers must prevent these errant photons from reaching the scope's focal plane.

In this column, I'll discuss some common examples of stray photons so you can recognize them in your images. In my next column, I'll follow up with a technique that takes care of a particular family of scattered light effects.

I have been an imager long enough to collect hundreds of examples, but I can show only a handful here. (More are in the associated video at www.Astronomy.com/Block.)

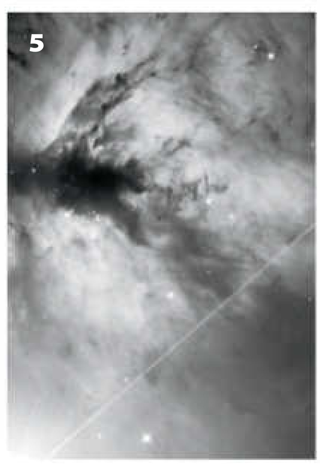
ALL IMAGES: ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA

In **Image #1**, multiple arcs fill the field. It's even more remarkable when displayed at full resolution because there are as many arcs as there are stars! These are the result of starlight reflecting off the shiny inner surface of the camera adapter nosepiece. Applying black-flocked paper to the inside of the tube instantly solved this issue.

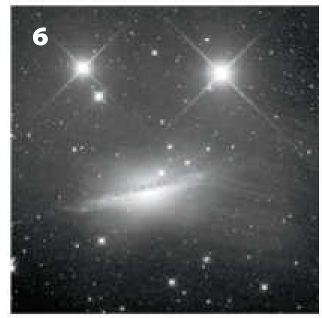
The scattered light of **Image #2** is equally impressive. All stars, especially the brightest ones, show a many-spoked radial diffraction pattern. A turned down edge (TDE) of the primary mirror scatters light to cause this effect. It's normal for the edge of a mirror to include some degree of TDE (as long as it is not in the usable diameter that you purchased).

Blackening the mirror's edge is one way to address unwanted sparkle. A knife-edge-machined circular mask on the 32-inch Schulman Telescope on top of Mount Lemmon hovers over the mirror on standoffs and completely eliminates the scattered light from the TDE.

The mysterious light in **Image #3** is truly diabolical. The glow would appear in sequential exposures and slowly fade, only to reappear later. The main culprit in this case was the filter wheel. Some use an infrared light to align filters. The light should turn off after a filter moves into position and before an exposure begins, but a software error can keep it on. The slow dimming resulted from a residual image in which charge remaining in thick chips fades. Although not related to the light, it made matters even worse.



Images #4 and **#5** demonstrate the difficulties of acquiring exposures near bright stars. It's often best to have bright stars in the field of view rather than just outside it because the latter case causes glows and gradients. In these images, brilliant Alnitak (Zeta [ζ] Orionis) scatters textured rings of light across the Horsehead Nebula (B33) and creates a severe gradient in the field of the Flame Nebula (NGC 2024). In addition, one of Alnitak's diffraction spikes runs through the field. I chose to remove this from the final image using a content-aware clone-type tool.



Warning … **Image #6** is about as bad as it gets! It shows a nearby bright star ruining the field with this setup. Shiny structures at the chip's edge cause specular reflections so complex that I have not found a good remedy for this case of scattered light. Sometimes rotating the camera and changing its orientation can help mitigate the reflections, but it isn't always possible.

And with that I leave you somewhat on a low note by presenting you with an image that would take more time to repair than to create in the first place! However, my next column will look at another interesting example, and I will demonstrate a technique that fixes it as well as other similar problems.

FROM OUR INBOX

Meeting Pluto

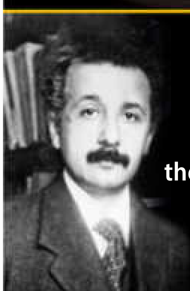
As we enter a new era of space exploration with NASA's New Horizons mission, one thing is certain — Pluto continues to captivate the imaginations of people, both young and old. Your July cover story, "Pluto: Up close and personal" (p. 22), gave us a revealing look at what exciting discoveries the future may hold. It is truly inspiring to know that over 16 months we will see Pluto as no one in history has seen it before. After all, science is as much about how we see the world, as it is about the world we want to see. — **Michael Aaron Gallagher,** Syracuse, New York

BROWSE THE "COSMIC IMAGING" ARCHIVE AND FIND VIDEO TUTORIALS AT **www.Astronomy.com/Block.**

COMING IN OUR NEXT ISSUE

NEW HORIZONS reveals PLUTO and its MOONS

When a NASA spacecraft flew past this distant world July 14, it forever changed our view of the previously mysterious system



Relativity turns 100

Albert Einstein's theory of gravitation altered the way astronomers see the universe

Hubble Deep Field: The picture worth a trillion stars

PLUS

- Big Island astronomy
- History and future meet at Lowell Observatory
- Behind the scenes of *The Martian*

Astronomy magazine

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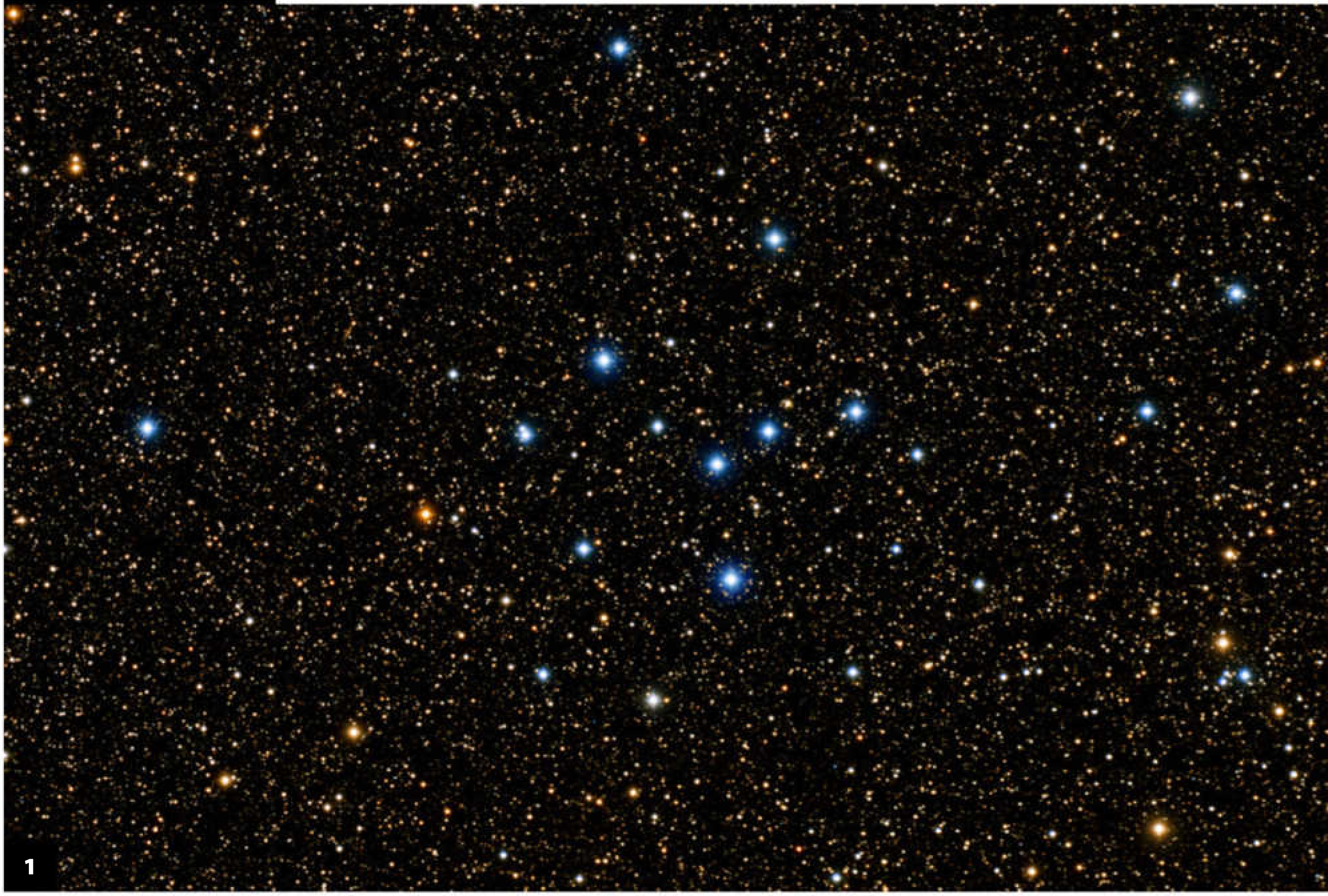
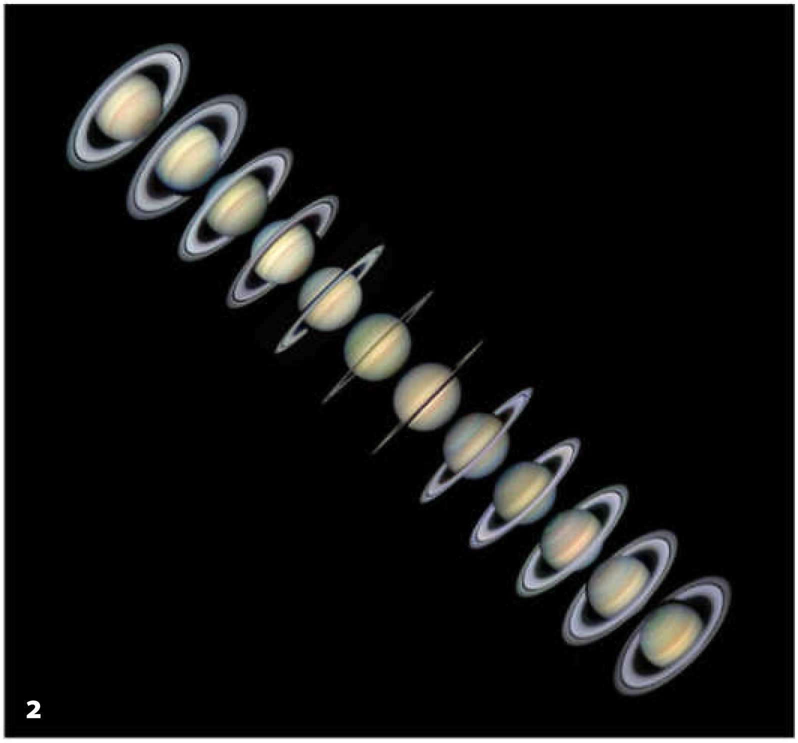
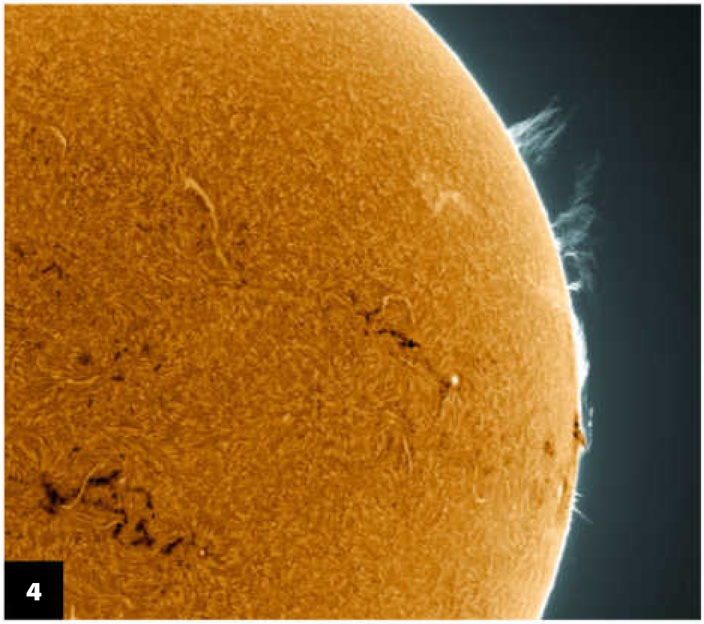

1

1. BLUE BEAUTY
The Black Swallowtail Butterfly Cluster (IC 4665) shines at magnitude 4.2 in Ophiuchus. IC 4665 is only 35 million years old, which accounts for the hot blue stars. The bright yellow and orange stars are not members of the cluster. (4-inch Takahashi FSQ-106ED refractor at f/5, SBIG STF-8300 CCD camera, RGB image with exposures of 210, 259, and 399 minutes, respectively) • ***Bob Franke***


2

2. SATURN TO THE 12TH
This montage chronicles the ringed planet from 2004 to 2015. The images show (top to bottom) Saturn's seasons changing from summer in its southern hemisphere to summer north of its equator. The ring tilt change is dramatic, but other alterations — such as the colors of the belts and zones — also stand out. Notice how apparent the blue coloration of the hemisphere pointing away from the Sun is and how this vanishes as more sunlight falls on that hemisphere. (various telescopes with various cameras, taken from England, Tenerife, Barbados, and Cyprus) • ***Damian Peach***

3



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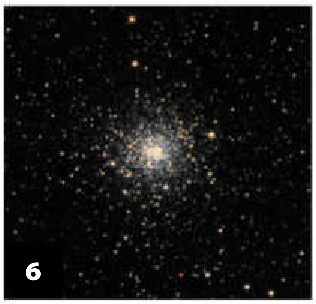

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3. DUE NORTH
Comet Lovejoy (C/2014 Q2) passed only 1° from Polaris (Alpha [α] Ursae Minoris) in late May. The comet glowed at 8th magnitude and had lost much of its previous green tone. A short dust tail points to the northeast, but the fainter ion tail is invisible, possibly due to the imager's suburban location. (8-inch Guan Sheng Optics reflector at f/3.8, Canon EOS 100D DSLR, taken May 29, 2015) • ***José J. Chambó***

4. SOLAR FLAIR
Our daytime star exhibited some spectacular activity while this photographer captured the frames to create this image. Although solar maximum occurred last year, our Sun is still quite active. (Coronado Solarmax 60 Hα telescope, Tele Vue 2.5x Powermate, Point Grey Chameleon3 CCD camera, stack of two images, each is the best 200 frames out of 1,000, taken May 17, 2015, from Carlsbad, California) • ***Behyar Bakhshandeh***

5. STUNNING SPIRAL
Barred spiral galaxy NGC 1398 glows at magnitude 9.7, measures 7.2' by 5.2', and lies 65 million light-years away. (16-inch RC Optical Systems Ritchey-Chrétien reflector, Apogee Alta U9 CCD camera, LRGB image with exposures of 15, 10, 10, and 10 hours, respectively) • ***Warren Keller, Steve Mazlin, Steve Menaker, and Jack Harvey***

6. STELLAR SWARM
Globular cluster M107 lies 21,000 light-years away in Ophiuchus. Although it appears relatively loosely packed, the magnitude 7.8 cluster contains some 200,000 stars. (10-inch Astro Systeme Austria astrograph at f/6.8, SBIG STL-11000M CCD camera, LRGB image with exposures of 170, 55, 50, and 50 minutes, respectively) • ***Ron Brecher***

7. CELESTIAL MIRROR
IC 2631 is a reflection nebula in the far-southern constellation Chamaeleon. It lies within a vast complex of dark nebulosity called the Chamaeleon I molecular cloud. Eventually, these clouds will spawn a star-forming region that will appear much brighter. (3.6-inch Borg 90FL refractor, Quantum Scientific Instruments QSI 683wsg CCD camera, LRGB image with 5 hours of exposures) • ***Remus Chua and Ivan Bok***

Send your images to:
Astronomy Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.

BREAK THROUGH

Slow ride to the suburbs

To fashion globular cluster 47 Tucanae (NGC 104), nature jammed roughly half a million stars into a sphere 120 light-years across. The giant cluster spills out of this Hubble Space Telescope view, which spans the central 10 light-years. Still, countless thousands of stars vie for attention. Astronomers recently targeted some 3,000 white dwarfs in this region. These stellar corpses — the remnants of Sun-like stars that shed significant mass in old age — migrate outward as they steal momentum from larger stars. The researchers found the white dwarfs traveling glacially at just 30 mph (50 km/h). NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)

MARTIN GEORGE describes the solar system's changing landscape as it appears in Earth's southern sky.

December 2015: A predawn spectacle

Planet watchers suffer through a lull on December evenings. As twilight fades early this month, not a single naked-eye planet puts in an appearance.

In the latter half of December, however, observers with a clear view of the western horizon should spot **Mercury**, which reaches greatest elongation on the 29th. The inner world then lies 20° east of the Sun and appears 6° high 45 minutes after sunset. Fortunately, the planet then shines at magnitude –0.6, bright enough to see against the twilight. If you can't spot it right away, binoculars will bring it into view. Target Mercury through a telescope around greatest elongation and you'll see a disk that spans 7" and appears slightly more than half-lit.

Several hours later, a string of planets will decorate the eastern morning sky. **Jupiter** rises first, around 2 A.M. local daylight time in early December and two hours earlier by month's end. You can find the planet drifting slowly eastward against the backdrop of southeastern Leo, though the Lion's stars can't hold a candle to Jupiter's brilliance. The giant world gleams at magnitude –2.1 at midmonth.

By the time twilight starts to appear, Jupiter has climbed high enough in the northeast to provide good telescopic views. During moments of steady seeing, any scope should show nice detail on the gas giant's 37"-diameter disk. The most prominent features are two parallel dark belts that straddle a brighter equatorial zone.

About an hour after Jupiter rises, **Mars** pokes above the eastern horizon. It lies one constellation east of Jupiter, in Virgo the Maiden. The Red Planet begins the month about 1° from magnitude 2.8 Gamma (γ) Virginis. But the eastward motion of Earth's neighbor eventually carries it near Spica. The two 1st-magnitude objects pass 4° from each other on the 21st and remain close through month's end. Use binoculars to study the color contrast between the ruddy planet and blue-white star. A telescope reveals Mars' bland disk, which measures just 5" across.

Trailing another hour behind Mars comes the brightest planet of all, magnitude –4.1 **Venus**. The brilliant beacon moves from Virgo into Libra during December's second week and ends the month at the doorstep of Scorpius. On the 31st, the planet appears as if it wants to become part of the Scorpion's claws. When viewed through a telescope at midmonth, Venus sports a 16"-diameter disk that is nearly three-quarters illuminated.

A fourth planet adds to the morning scene in late December when **Saturn** reappears from behind the Sun. The ringed world rises during morning twilight and climbs about 10° high an hour before sunrise. On the 31st, the magnitude 0.5 planet lies 10° to Venus' lower right. Although a telescope easily reveals Saturn's famous rings, which span 35" at month's end, better views await in the new year once the planet climbs higher in a darker sky.

The starry sky

I often mention to planetarium audiences — and, rather cheekily, to colleagues when I visit the Northern Hemisphere — that southerners are fortunate to have such a lovely view of the Milky Way. Such bragging doesn't work on December evenings, however, because the Milky Way hangs low in the sky and we can't see our galaxy's spectacular center.

But the southern half of the celestial sphere contains plenty of other wonderful sights. One aspect of special interest is that the three brightest stars in the night sky — Sirius, Canopus, and Alpha (α) Centauri — all reside in the celestial southern hemisphere. This naturally leads to the question of how many of the sky's brightest stars are visible at any one time. Let's take a look at the situation on December evenings assuming you observe from a latitude of around 35° south.

Following the three brightest nighttime stars, the only other one with a negative magnitude is Arcturus. Unfortunately, neither Arcturus nor the next brightest star, Vega, appears on December evenings.

But the situation improves dramatically after that, with the five subsequent stars all on display during these warm summer evenings. Yellowish Capella, which shines at magnitude 0.08, hugs the northeastern horizon from its perch in the northern constellation Auriga the Charioteer.

The star at lucky number seven is blue-white Rigel in Orion the Hunter. Gleaming at magnitude 0.12, it actually looks brighter than Capella to us because it stands much higher in the sky. Capella's light has to pass through much more of Earth's atmosphere on its way to our eyes.

Shift your gaze toward the eastern horizon to pick up Procyon in Canis Minor. This magnitude 0.34 sun appears rather isolated, unlike many of the sky's brightest stars, because the rest of its constellation is nearly devoid of prominent stars.

The leading light of Eridanus the River — magnitude 0.50 Achernar — comes in eighth on the list. It shines high in the south on December evenings and appears significantly more isolated than Procyon.

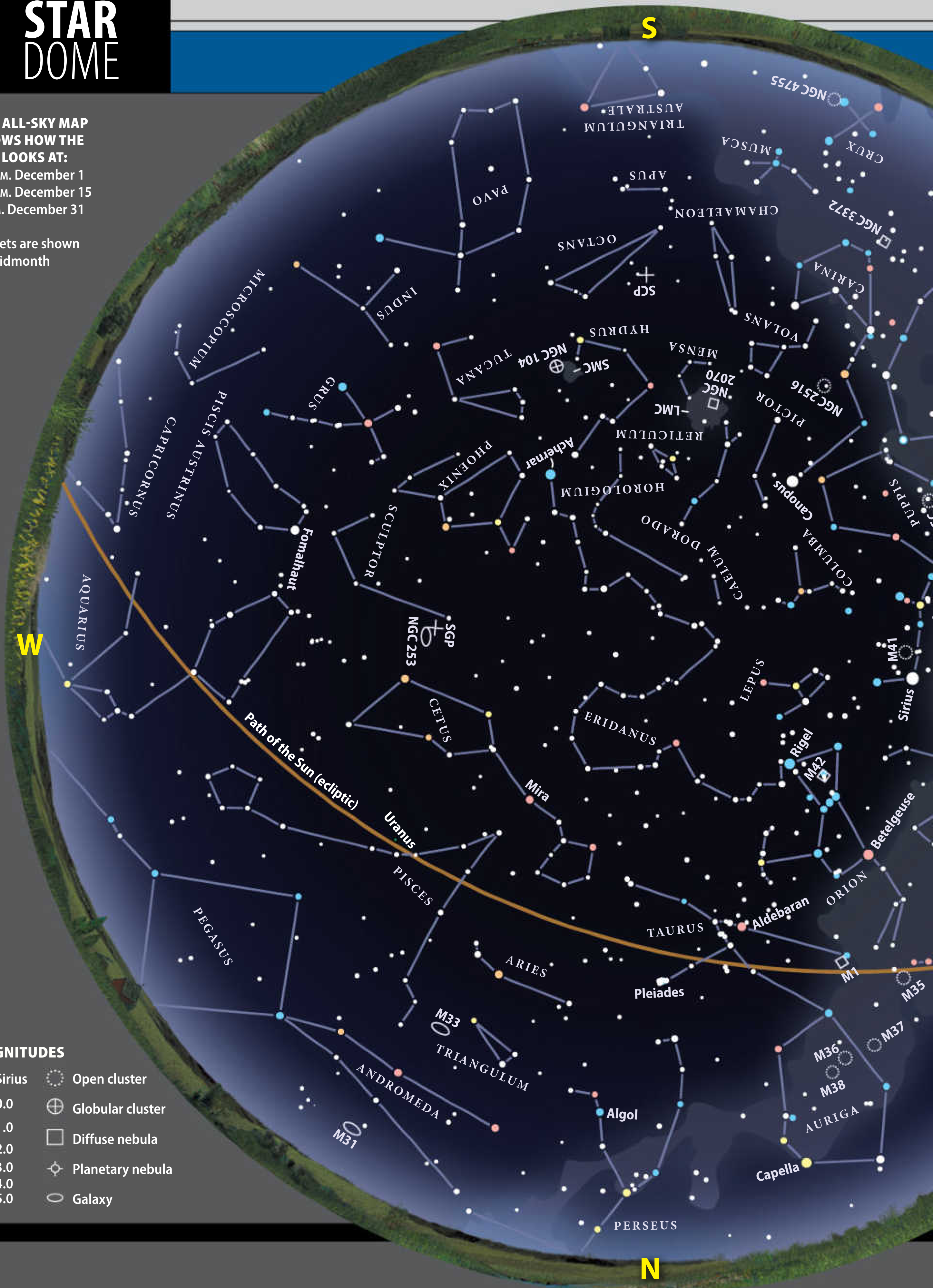
After Achernar, the list of brightest stars contains an interesting entry. Betelgeuse resides in Orion, diagonally opposite Rigel in relation to the Hunter's three belt stars. Betelgeuse's brightness changes significantly over time, so its place among the sky's luminaries goes up and down. It has reached magnitude 0.2 at its brightest but has dimmed as low as magnitude 1.2. Astronomers often quote an average of 0.58, placing it ninth on the list.

We have to head back to Centaurus for number ten: Beta (β) Centauri at magnitude 0.60. It sits just 4° west of Alpha, with the two forming a brilliant pair just above the southern horizon. So there you have it — eight of the night sky's ten brightest stars are yours tonight simply for the asking. I wish you clear skies.

STAR DOME

THE ALL-SKY MAP SHOWS HOW THE SKY LOOKS AT:
11 P.M. December 1
10 P.M. December 15
9 P.M. December 31

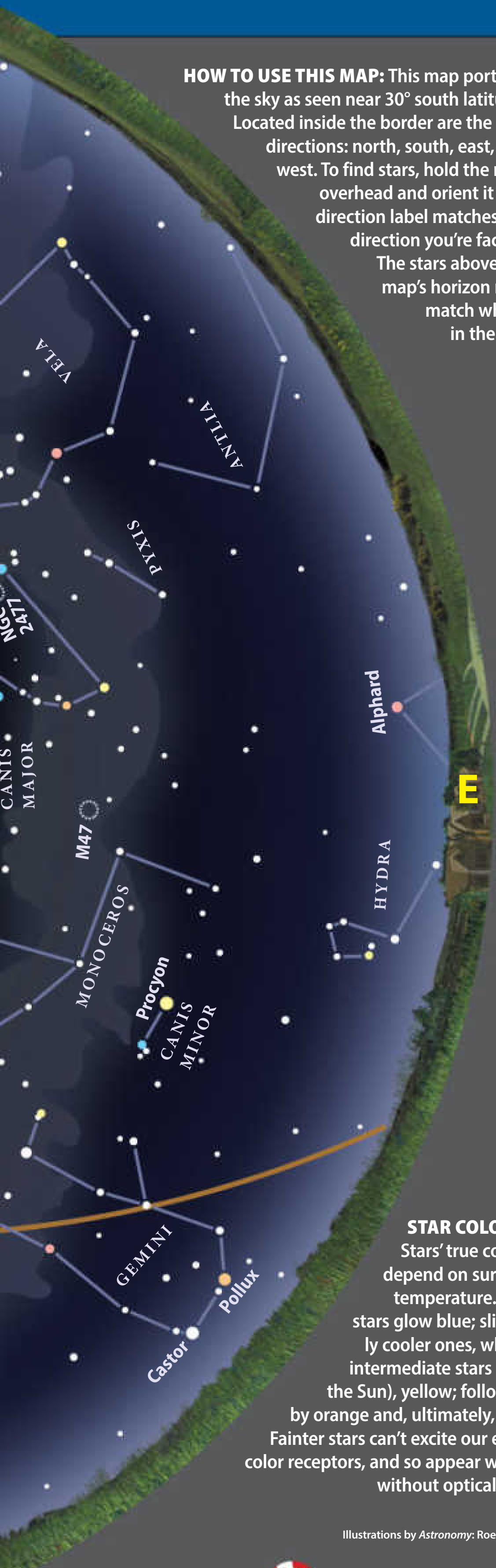
Planets are shown at midmonth



MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy



HOW TO USE THIS MAP: This map portrays the sky as seen near 30° south latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

STAR COLORS: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white without optical aid.

Illustrations by *Astronomy*: Roen Kelly

DECEMBER 2015

Calendar of events

3 Last Quarter Moon occurs at 7h40m UT

4 The Moon passes 1.8° south of Jupiter, 6h UT

5 The Moon is at apogee (404,799 kilometers from Earth), 14h56m UT

6 The Moon passes 0.1° south of Mars, 3h UT

7 The Moon passes 0.7° north of Venus, 17h UT

9 Asteroid Psyche is at opposition, 14h UT

11 New Moon occurs at 10h29m UT

14 Geminid meteor shower peaks

17 The Moon passes 3° north of Neptune, 8h UT

18 First Quarter Moon occurs at 15h14m UT

20 The Moon passes 1.2° south of Uranus, 1h UT

21 The Moon is at perigee (368,417 kilometers from Earth), 9h00m UT

Mars passes 4° north of Spica, 12h UT

22 Summer solstice occurs at 4h48m UT

23 The Moon passes 0.7° north of Aldebaran, 20h UT

25 Asteroid Euterpe is at opposition, 5h UT

Full Moon occurs at 11h11m UT

26 Uranus is stationary, 11h UT

29 Mercury is at greatest eastern elongation (20°), 3h UT

31 The Moon passes 1.5° south of Jupiter, 18h UT